Interactive Olfactory Surfaces

The Wellness Collection - *A Science Fashion Story*

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

Abstract

"Physics Is A Function Of Size. . . "

The aim of the research is to create a new interactive communication system by **'re-cabling'** fabrics for releasing fragrances in 21st century fashion design. A new development, taking inspiration from biology, conjures up *Multi-Sensorial Fabrics* - based around the sense of smell. Using the theory that 'Smell Is Nanotechnology' and that biology works by nano-machines, biological actions can be *miniaturised (*such as 'sensing' in the animal world) to create an integrated system called THE WELLNESS COLLECTION. Fragrances (and eventually medication, monitoring devices and digital information) will be actively *'pulsed'* electronically through a cabling device system which will 'mimic' the human senses and in particular the scent glands in our bodies and be literally incorporated into the fabric structure. Technology with therefore be integrated in fabrics and *carried* in invisible clothing. The system also acts as a new vehicle for designer perfumes, reducing the application of alcohol on skin and microencapsulation.

Traditional textile design concerns *passive* issues relating to colour and texture (and performance purposes to a certain degree). However, this research concentrates on a more *active* approach to textile design, introducing the *living active garment* as a **second skin.** The aim is to combine a number of contrasting areas from the Arts and Sciences. For example : -

Perfumery. Fashion Designs. Textile & Fibre Technologies. Space Age Clothing. Biosensing Techniques. 'Micro Tube' Technology. Fluid Control. 'Smart intelligence'. Human Biology & Psychology. Human Skin, Circulation & Nervous Systems. Medical Textiles. Controlled Drug Delivery Systems. Alternative Therapies. Nanotechnology.

Although some might consider this project to be high risk, it is a general fact that creative and 'novel' research originates from multi-disciplinary fields. Emphasis on this important fact must be acknowledged throughout the thought process of the following project which is documented as a thorough 'library' of valuable research information. The S*cience Fashion* approach may therefore seem very futuristic, but as technology itself reduces in size such an approach becomes increasingly realistic.

The thesis describes the design thinking and methodology undertaken for the study of a PhD design based research programme which has been studied over a period of three years. (The first

year was undertaken on an MPhil programme with direct transfer to PhD).

Thesis Guide

Overview By Jenny Tillotson

This guide demonstrates how I went about the research programme, illustrating what measures were taken for *practical* aspects of the project that are described towards the end. I will endeavour to explain the necessity of ordering for each chapter and the methodology chosen.

Ordering Of Chapters In Thesis

Quotes Relating To Research

During the research significant quotes were collated which acted as signals and inspirations, and were encouraging in their thought process. Some were extracted from personal research letters, interviews or telephone conversations between myself and relevant industries - others were picked out of novels, websites or other reference sources. Lucille Khornak, a fashion photographer in the early eighties, wrote a particularly relevant book in 1982 in which she collected expressions, drawings and photographs from 100 Designers and predicted how the state of the fashion industry would be in the year 2001. Although this date is now only 4 years away the quotes she chose from 5 major fashion houses are stimulating and dynamic.

Chapter 1 Introduction & Summary

The Introduction explains my background as an Artist, how the research began and the reasoning behind its *multi-disciplinary* approach which was very much encouraged by my Supervisors. The Summary briefly outlines the project, *INTERACTIVE OLFACTORY SURFACES,* introduces **THE WELLNESS COLLECTION** and explains what is meant by 're-cabling' clothing as a *living active, reactive* - and invisible technology for the 21st century.

Chapter 2 Multi Sensorial Surfaces

The research commences by touching on *the senses* and though this may be viewed as a biology lesson it is vitally important to stress how much biological actions are an inspiration to the project. Sensory imagery and , in particular, smell, are the key issues in this chapter.

Chapter 3 Perfume Revolution

Perfumery is an enormous business and one that cannot successfully be summarized easily. However the purpose of this chapter is to emphasise the revolutionary impact this research *could* have commercially for Designer Fragrances in the 21st Century. CoCo Chanel revolutionised perfumery in 1921. My Supervisor, Dr George Dodd, has often pointed out the potential behind *smart* interactive olfactory fabrics as a new vehicle for carrying perfume. The fabric structure would therefore be a rich reservoir for fragrances to travel through.

Chapter 4 Fragrance Delivery

Having briefly ascertained the History Of Perfumery an enormous amount of time was spent researching different areas of Fragrance Delivery - including 'pheromonal mating' methods by insects. It was not only necessary to find out exactly what was technically available but to present my work to the Fragrance Industries for feed back on defining a new system.

Chapter 5 The Triggers

The path of this chapter is an overview of industrial and medical 'sensing' techniques and has been particularly dedicated to smell detecting - a thing of the future, but evidently possible. 'Sensing' is the key source of the project's interactivity and mystery. It concerns what goes on inside a smart fabric, assuming that the established 'cabling' system contains brain power and bionic information. What makes people click? What triggers our reactions to certain things? Why did we do that and so on. *Triggering* is the signal from one action for another action to take place. We are entering an exciting era of **bio**sensors which simply means sensing or triggering from the body.

Chapter 6 Dynamic Surface

This chapter concerns a documented library of research but also stresses that a 're-cabling' fabric is comparatively similar to the body and human skin. We are, after all, a bunch of cables and intelligent cells, delivering blood, signals and bodily fluids around the body's tubing system. Recent examples of active dynamic surfaces are listed in this chapter, stressing the *dynamic surface* as an outer protective shell.

Chapter 7 Smart Intelligence

The word 'smart' is thoroughly defined (not to be confused with smart in the glamour sense of the word). Clothing is the *invisible technology* for the 'Nomadic Approach'; a perfect *carrier* for transporting, for example, medication, fragrances and information, everywhere with you. The chapter concentrates on 'intelligent' aspects in a number of intriguing areas. Although the concept of 'Smart Intelligence' is nothing new, technology is reducing in size so rapidly that it will soon be incorporated into clothing.

Chapter 8 The Electronic 'Pulse'

At this stage the research diverts off into another dimension, introducing the medical industry and 'drug delivery'. Other forms of an electronic 'pulse' are mentioned including gardening equipment and peristaltic pumps. Medical tubes are discussed in great detail as the carrying mediums for 'delivery'. The chapter concludes with a brief summary of complementary therapies, emphasising the alternative *Science Of Healing,* in contrast to orthodox therapies. This is subsequently used as an inspiration behind the final working *interactive* designs.

Chapter 9 Delivery Experiments

This chapter has been separated into three sections - *first, second and third year*. The first year concentrates on the MPhil 'Surface Design Of The Senses' which lead up to the PhD. The second introduces the practical studio-based work which involved constructing models of textiles. The third includes experiments with different sized pumps, ranging from large industrial pumps to nano-fluid devices. Chapter 9 concludes with fashion designs for *The Wellness Collection.*

Chapter 10 Fabrics Files

Chapter 10 briefly documents synthetic fibres, fibre optics and a variety of textile technologies necessary for the future integration of tubing and micro machinery into fabric design. Various textile experiments were carried out at the Royal College of Art using micro bore medical tubings, woven, knitted and sewn into fabric samples.

Chapter 11 Medical Textiles

Medical textiles looks at the *next second skin* and discusses earlier and most recent developments that relate to the specific components and skin contact actions of drug delivery in fabrics. Human skin is heavily targeted by pharmaceutical companies who are always looking for something novel. The purpose of this chapter is to stress how non-invasive medical textiles will soon be totally integrated as part of clothing.

Chapter 12 2020 50/50

This chapter discusses designing for our elderly generation, introducing 'Matey Materials & Friendly Fabrics'. It explains how beneficial *The Wellness Collection* will be by the year 2020.

Chapter 13 Nanotechnology

Although the vision of Nanotechnology is approximately twenty years away, this chapter is particularly valuable to the project because it emphasises *size* dimensions. It summarises *Nanotechnology* - which is a science that literally borrows techniques from biology.

Chapter 14 The Wellness Conclusion

The conclusion summarises the major research discoveries, their implications, the final working proto type and indicates what the next steps might include with respect to post doctoral work in the UK and abroad. It also offers the opportunity to discuss a documentary film - **The Wellness Collection** - *A Science Fashion Story* which thoroughly supports this thesis and has been filmed during the write up process.

Research Methodology & Approach

The methodology for this research project involved the gathering of *Information Techniques* and illustrations, photographs and diagrams from wide ranging subject areas as mentioned in Chapter 1.2 on Multi-Disciplinary Research. A substantial 'library' was organised from the early stages in October 1994 and collected throughout the research communicating process. This was executed by attending various Trade Fairs, Exhibitions, Conferences, Festivals, Fabric Fairs, Fashion Shows, by collating information from the internet and promotional literature from manufacturers, by visiting major International Research & Development Centres and meeting Scientists in the UK and abroad (France, Holland, America, Switzerland and Germany) and by watching relevant television programmes. All of the above are fully documented in the Appendices, page 137 and Bibliography, page 162.

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Figures & Illustrations

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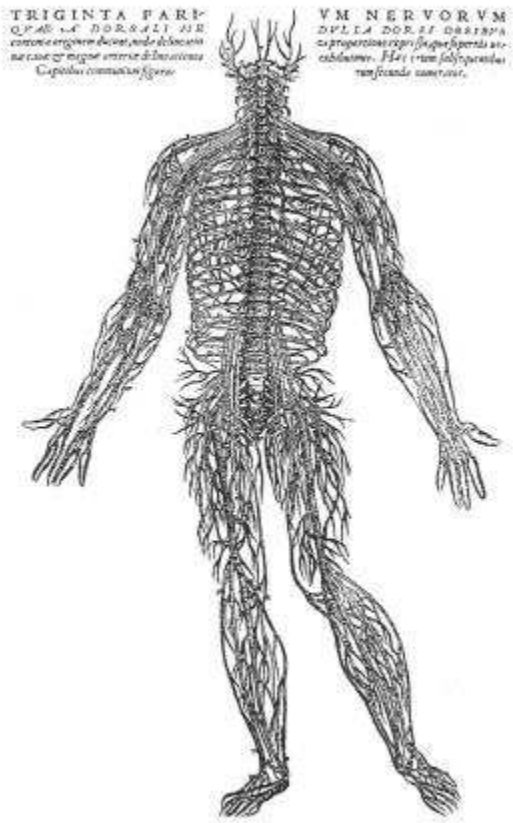
University of Leeds	Dr J. Crighton
Defence Clothing & Textiles Agency	Dr Richard Scott
Royal Military College of Science	Dr C M Friend

Quotes Relating To Research

"The best way to predict the future - is to invent it"

Alan Kay [1]

"Fashion is the recognition that nature has endowed us with one skin too few, that a fully sentient being should wear its nervous system externally"



J.G.Ballard [2] (fig. 1)

"Personally, it is interesting to find out that innovations in drug delivery systems can impact on industries as distant as textiles"

[1] *Nanothinc* website (Apple Mac computers) 1997
[2] Nickerson C. quoted in *Artforum* 1997

Dr Richard Mannion [3] 1995

"Science is about studying nature and describing what already exists -
- Engineering is about taking what we know and making new things"

Eric Drexler [4] 1995

The scent organ was playing a delightfully refreshing Herbal Capriccio - ripping arpeggios of thyme and lavender, of rosemary, basil, myrtle, tarragon: a series of daring modulations through the spice keys into ambergris; and a slow return through sandalwood, camphor, cedar and new - mown hay back to the simple aromatics with which the piece began. . . .

Aldous Huxley [5] 1932

"I think it is a question of being honest and modern"
I'm against the idea of romanticism and that chemicals are supposed to be bad.
We're moving forward toward the next century, synthetics are forcing us to think ahead"

Liza Bruce [6] 1995

[3] Pharmaceutical & Analytical Development *Ciba Pharmaceuticals* UK
[4] Drexler. E. Institute For Molecular Manufacturing, California, *Nanotopia* Horizons BBC 1995
[5] Huxley. A. *Brave New World* 1932
[6] Jackson.J. The Techno Revolution. Harpers Bazaar 1995

Alongside the interactive or reactive possibilities of new fibres, synthetic textiles will bring about the softening or 'humanising' of information technology by allowing it to be integrated with our clothing - anything that can be CARRIED by a fibre can be woven or knitted into our garments. Soon all technologies will be wearable - the ultimate in computer "softwear"

Susannah Handley [1] **1994**

"Isn't a fabric that is alive in some way scary?
It might strangle you one day"

Katherine Hamnett [2] **1994**

"Who knows? In the next century, clothes shops may replace pharmacies..
If these fabrics really happen, then this is the biggest breakthrough in centuries"

Colin McDowell 3 1994

"If odours may worke satisfaction, they are so soveraigne in plantes and so comfortable that no confection of the apothecaries can equall their excellent vertue"

John Gerarde

"One day whole telecommunication systems will be built into the fibres of our clothing:
Goodbye office, goodbye laptop. Hello, global network jacket"

Nilgin Yusef [4] **1996**

"Clothes are more than ever about function and performance.
Increasingly art and science are crossing over"

Joanna Bowring [5] **1996**

[1] Handley.S. Fashion Historian in *Herald Tribune* 1994
[2] Hemblade.C. Amazing Technological Dream Clothes, *The Guardian* 31 March 1994
[3] Hemblade.C. Amazing Technological Dream Clothes, *The Guardian* 31 March 1994
[4] Yusef.N. Test Tube Babes - *The Sunday Times Magazine*. 3 March 1996
[5] Yusef.N. Test Tube Babes - *The Sunday Times Magazine*. 3 March 1996

Fashion Quotes From 1982 [1]

15 years ago (1982) - Fashion Designers

predicted how they perceived the future

to be for the fashion and textile industries

- In The Year 2001

Thierry Mugler 1982

Fashion will change dramatically in the coming years. One will find it less and less important to be 'fashionable'. Good clothes - garments well designed and well made for the purpose of protecting the body and enhancing the personality - will prevail. Fashion will be more human, closer to the needs of the people in terms of their being and well being, not "well showing". This is the direction in which I am now working.

Karl Lagerfeld 1982 (For the House of Chloe)

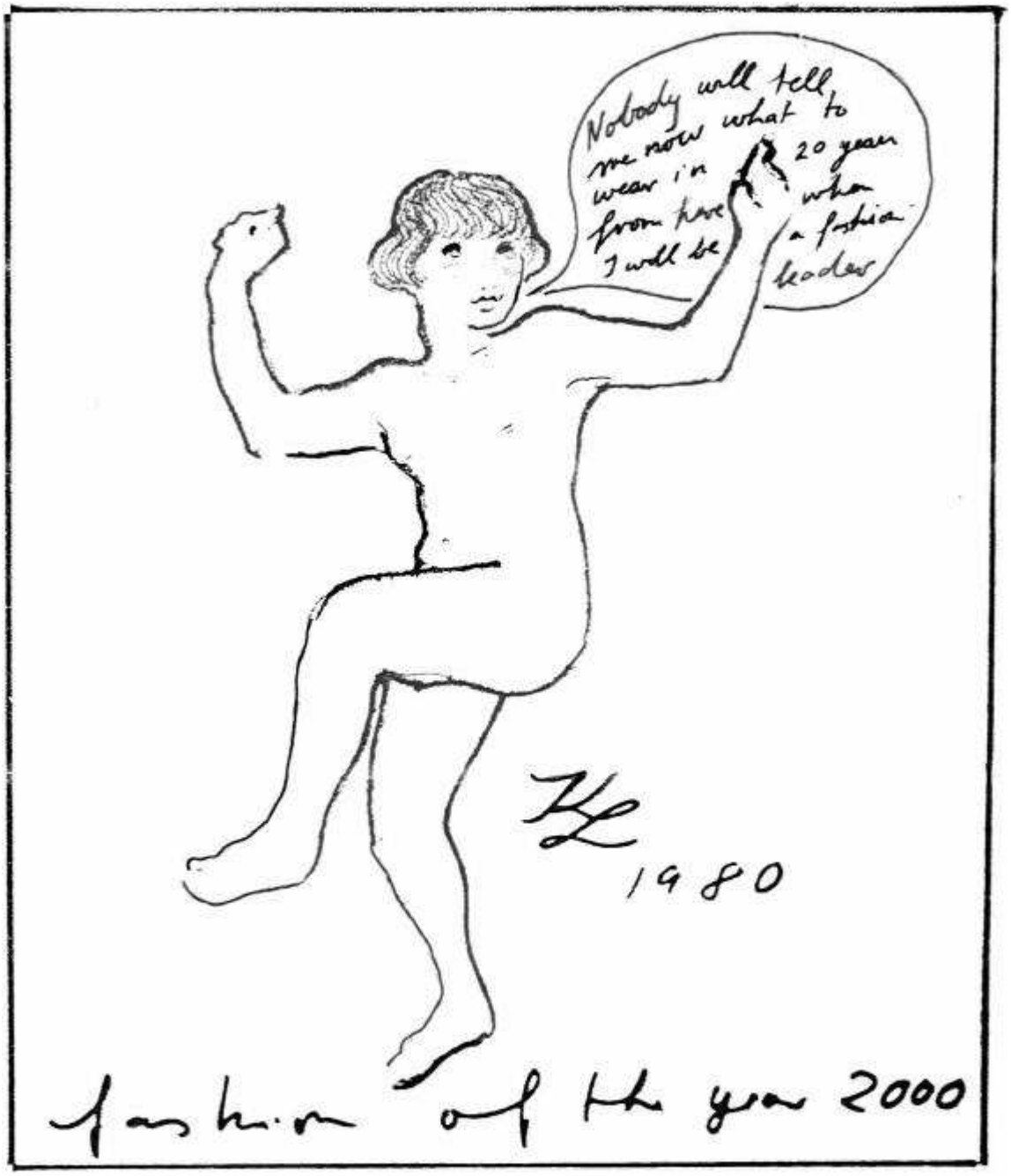
Deep changes in fashion will come with new developments in fabric technology. The body is the most important thing of the future and was not designed for life outer space, not yet anyway. It may take another two or three thousand years for the body to evolve. Designers are like musicians. The materials are our notes. We have to play with them and each one of us has to make his own music.

Will fabrics eventually become computerised? Everything will be, us included.

People are becoming programmed - it is dangerous, but it is the future. (fig. 2)

[1] Khornak. Lucille, All Designer Quotes from "FASHION 2001" written in 1982

Deep changes in fashion will come with
new developments in fabric technology.



Will fabrics eventually become computerised? Everything will be -
Us included. People are becoming programmed. It is dangerous.
But it is the future.

Karl Lagerfeld Quoted In 1982

Jean Paul Gaultier 1982 [1]

Spray on the latest fashion and dispose of it at the end of the day. Spray on latex body suits in the same way as we spray on hair-spray. A persons weight will not be of concern. The image will change. We will accept our 'second skin'. The sewing machine will no longer exist. The most dramatic change will be the development and construction of new fabrics. Fabrics -perhaps even the term 'fabric' will change - will evolve into something unique to envelop the body - a new way of covering the human form. The future will bring another movement forward, possibly involving "moulded" clothing - a new procedure and a new kind of apparel that will be made from a mould filled with a substance that will in turn give the clothing form. Fabrics will be influenced by the weather. The temperature and atmosphere will be controlled on the actual fabric. The fabric itself will be the 'central focus', not the length of a garment.

Donna Karan 1982 (for Anne Klein)

Fashion is the end result of what is happening in the world. We could be living in glass domes and machines will be creating our atmosphere. We may not be eating meat anymore, so we wont produce cattle for food or for fabric. Technology will produce new fibres that will protect us from what is happening outside. The creative minds will use the technology and make new fabrics look good on people. There will be a time when we will have to live through computers and chemistry and even though it seems strange and impersonal now, when it happens, when we are living it minute to minute - we wont resent it.

[1] Khornak. Lucille, All Designer Quotes from "FASHION 2001" written in 1982

Courreges 1982

Mesh in the construction of fabric, which serves as the mainstay of clothing, takes on increasing importance. Warm yet ventilated, stretchable in all directions, adaptable to all body forms and body movements. Mesh and body stockings will be the logical answer to evolution as it allows one to live casually and acts as a 'second skin'.

Chapter 1

1 The Introduction

1.1 General Introduction

Smell

Nothing is more memorable than a smell. Odours drive our emotions, warn us of danger, influence our body chemistry, lead us into temptation and steep us in luxury. The Perfume Industry has a turn over of 1.8 US$ billion dollars every year (ref. 1), creating fine fragrances which disguise our natural body odour and keep the Couture Houses alive. Scents are beginning to make scientific sense as sexual attractants, suggesting that pheromones [1] do exist.

Wonder Influences

The origins of the research began in 1991, after graduating from St Martins School of Art with a BA(Hons) in Fashion Communication & Promotion. As one of the most prestigious courses specialising in fashion journalism, it is necessary for students to produce a forecasting magazine for the graduating shows. To avoid the *run-of-the-mill* journalistic port folio a three dimensional, musical, pop-up, journalistic book was created, inspired by pure fantasy, the meaning of **WONDER** (ref. 2) and based around 'the senses'. The possibilities for stimulating all 'senses' as a means of communication had only just begun its research route, although at that stage little possibilities were discovered for pursuing **WONDER**.

From Style To Science

The following few years led to a profitable career as a Freelance Fashion Stylist, Researcher & Journalist for International and British fashion magazines and newspapers such as : - *The Daily Telegraph Weekend Magazine, British & French ELLE, Hanatsubake* and *Fashion Dayori*,[2] *Harpers & Queen, The Independent and Vogue.* Experience in the music industry followed at *A&M (BMG) Records and Arista Records,* as well as experience in advertising campaigns, fashion shows, public relations and as a College Lecturer in Fashion Communication & Media. The styling opportunities were endless but creatively the direction was unfulfilled and only partially resolved. *Science* became more of an issue, crossing over into the Arts, emphasising *surface design* and the *physical and conscious action* of fashion design. It grew apparent that by embracing past experience and knowledge, by researching into all the senses and referring to

[1] Chemical messages influencing physiology and behaviour of the same species

Science and Human Biology a suitably new technology could be made available for future fabric and clothing.

RCA - *Surface Design Of The Senses*

Three years after leaving St Martins the WONDER book ended up at the Royal College of Art, in the School of Fashion & Textiles. Embarking on a rather ambitious MPhil by Project, the research immediately concentrated on all five senses, with an MPhil called *"Surface Design of the Senses"*[1]. From an early stage it was anticipated that the practical work would include microchips or gadgets found in children's toys and greeting cards. These would illustrate 'sound' and 'vision' and other decorative details and could therefore turn into a 'gimmick'. On completion of the first year it became quite clear that the original proposal was too broad-based and a more in-depth research mode was suggested, subsequently refined to a PhD. The developing research *and* previous experience in the Fashion Industry had led to an awareness of interactive designs, including a growing conviction of their inevitable suitability for *future technology wearables*. The importance of these factors, combined with a growing knowledge of the senses, formed a core for a PhD.

Refining To PhD

Although the MPhil had been fully successful it needed to be focused on one particular '*sense'*. This was an easy task, as 90% of '*taste*' is smell and EEC legislation on nutritional laws would disallow edible textiles. Interactive 'sound' textile research is underway at the RCA, so by taking the *human body and the flow of life* as the visual foundational structure, concentration was focused on the *super-sensitive* sense - the one remaining power mystery - ***Smell.***

New Technical Era

"Think small, think very small, because the future is getting small" (ref. 3)

After reading the novel **Perfume - *The Story of A Murderer*** [2] olfaction was chosen as the most powerful and intriguing area for *design-based* research. It is the least researched of the senses and one that will - over the next century - find discovery in a completely new light. We live in an audio-visual world. Our sense of sound and sight feast on computer technology, digital recordings, CD - ROM and virtual reality. Fashion and textile design is entering a new era of

[2] Japanese Fashion Magazines

[1] Research project investigating *sensory fabrics* and paper engineering skills (1994-1995)

[2] By the German author Patrick Suskind

technical interaction with *'intelligently smart materials'* enclosing us in our personal micro environments. It seems now that science is changing, as smell becomes the latest scientific frontier and the buzzword, *nanotechnology* [1], builds our bubble for the future.

1.2 Multi-Disciplinary Research

State-Of-The-Art-Information

As a new development taking its inspiration from biology, the aim is to invent ***the second skin***. This is the main aim- action related to human skin, a skin that mimicks the skin which covers and protects our bodies. Textiles are constructed for *21st Century therapeutic fashion designs.* This is the core for the formation of an ambitious multi-disciplinary project, crossing over into many areas and requiring state-of-the-art information. One of the key objectives throughout researching 'the senses' has been to combine the Arts with Medical Science. Cross-migrating of diverse multi-disciplinary areas relates to the following :

Innovation. 'Smart intelligence'. Fashion Designs. Textile Technologies.
Alternative Therapies. Human Circulation & Nervous Systems. Human Skin.
Medical Textiles & Controlled Drug Delivery Systems. Fine Fragrances.
Space Age Clothing. Human Biology & Psychology. Nanotechnology

Technology Of The Senses *Could Be* The Future Of Fashion

These particular fields needed bridging together to create a totally novel and sensual *interaction,* using *Smart Intelligence* - never seen, felt or smelt before. For this reason it is important to acquire an acute awareness of how people sense and react to their environment and how technology affects them. Smart materials give us the opportunity to investigate new areas of the human condition. By implanting intelligence into materials, in this case fabrics and new fibres, we create a responsible technology, offering unconventional solutions to global problems. Architectural Fabrics could change and become an almost 'living organism', adapting to climate and inhabitants needs. *'Future Feeling Fabrics or Clever Cloths'* make you closer to the world, your environment, body, senses, mind & soul. They are, however, not only smart but also sensual, stylish and beautiful. Technology of the senses could well be the future of the fashion industry.

[1] The manipulation of individual atoms & molecules to build structures to complex atomic specifications

This is the future and purpose of textile design

1.3 The Summary

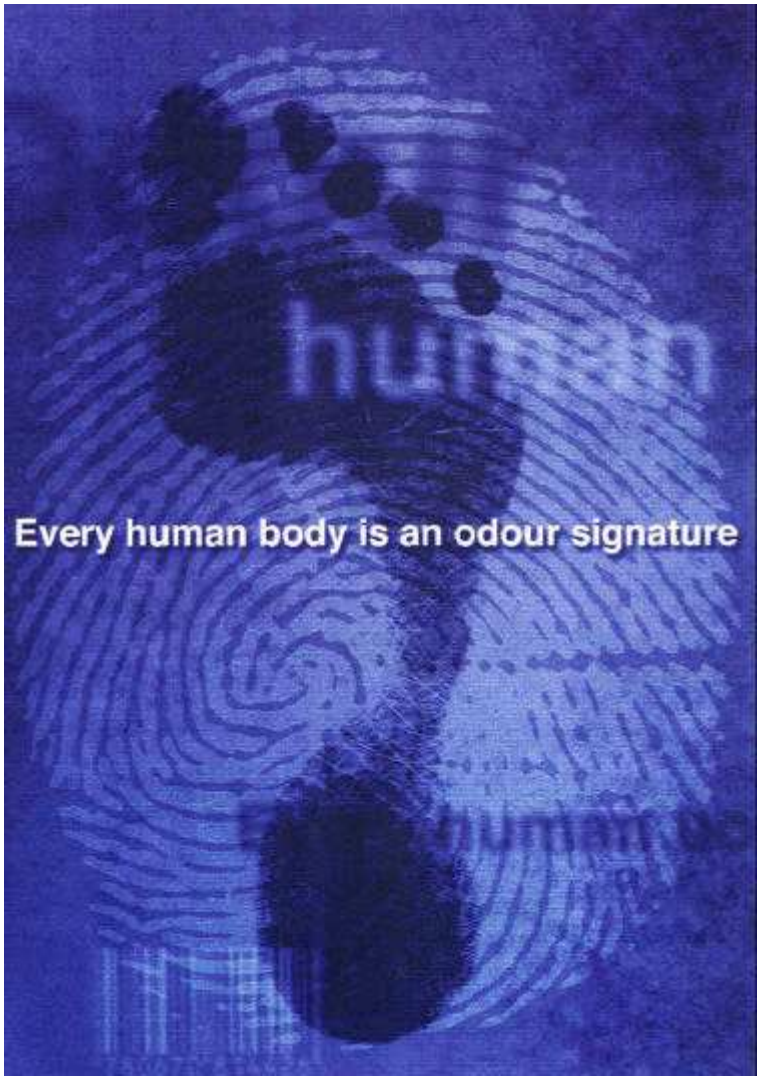
The Second Skin

Fashion, textiles and perfumery cross-over into medical scientific areas. The objective is to make fashion, textiles and the garment itself much more active by *boosting* therapeutic qualities. This will be achieved by enforcing intimate relationships between clothing, fabrics, fibres and colours in order to increase the well-being of the body. Clothing has an *action* which can be enhanced more readily, improving the properties of textiles, shapes, textures and all fashion components. Particularly fascinating interests lie in the interaction between humans and their ***second skin,*** whether this be through our own personal interaction with the skin or interactions between two individuals. Our natural skin is a rich reservoir of chemicals, facing outwards *and* inwards and by interacting with the ***second skin***, it gives a second opportunity for action. Human skin is heavily targeted by pharmaceutical companies in *transdermal delivery* which will be discussed in Chapter 11 on Medical Textiles. The research subsequently involves improving all capacities of the garments to increase the therapeutic action, so preventing, detecting and - eventually- treating diseases.

"The 'Cutting Edge' Of Technology Is The Cutting Edge Of Fashion"

The methodology used, by way of documenting a fully comprehensive 'research library', conjures up a wide mixture of innovative, complex and intriguing subjects. By collating as much available knowledge, technical and scientific information (as well as fantasy and fiction) as possible a foundation for new developments in clothing and sensory, *intelligent* fabrics will commence. This will enable all five senses to be together in this outer fabric shell, actively partaking in the development of the human being.

"Every Human Body Has An Odour Signature" (fig.3)



The purpose of this research concerns new ways of displaying fragrances, in state-of-the-art contemporary *interactive* fabrics, which have been especially 'triggered' by a body's *individual* language or odour. By combining fabric, the most familiar, tactile and friendly material in our lives, with the forefront of technology - entirely new ways of communication and self diagnosis, towards a healthier life, will be achieved. This is a highly original and ambitious project, driven very much from the *'fashion end',* contributing towards futuristic applications. The overall concept and seminal ideas being explored are revolutionary and of wide interest to medicine, perfumery, fashion and industries looking for something which is really '*novel'*.

1.4 Global Re-Cabling System

Scratch & Sniff **Progression**

The research blends the scientific and psychological aspects of life. One of the primary functions is to act as a global, sophisticated odour communication system using micro-delivery systems, biosensors and tubes, by *'re-cabling,* clothing and pushing the 1970's passive method of 'scratch 'n sniff' to a completely new dimension. **This old technology of microencapsulation can never be a *living* active technology.** The process has not progressed for many decades and is still at the stage of over saturated smelly micro-encapsulated surfaces, magazine advertising inlays and fragrant fabric surfaces. Inevitably, these inevitably fade and wash out, leaving little scope for interaction.

From Design To Delivery

Startling possibilities for novel approaches are increasingly being discovered in controlled & transdermal drug delivery systems. Further avenues include medical devices, fragrance chemicals and intelligent fabrics, into which thorough research has been achieved. Consequently, these approaches will lead to a new breakthrough in Fashion Design, with respect to awareness of the possible ***action of the clothing.*** This might include the delivery of any source of information e.g. :- fragrances, drugs, sounds, texture, colour vibrations, digital information and temperature.

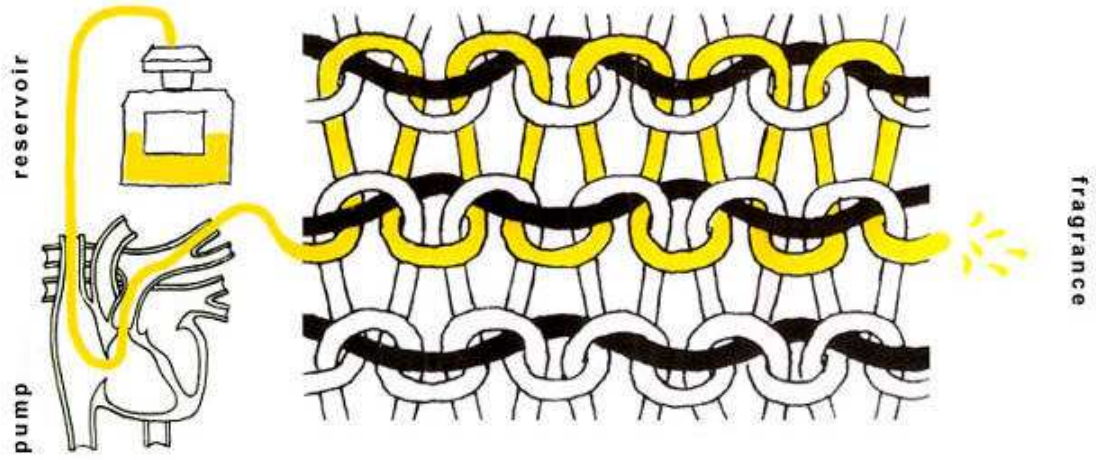
Cabling **Textile Technologies**

Using the olfactory sense as the overall vehicle intelligent 'software' structure, current sensing techniques and miniaturised drug delivery systems with micro-bore tubings are integrated together. Fragrances can therefore be released through laser holes that are drilled at strategic points. Alternatively a miniaturised release mechanism could be modified as a clothing element. The '**cabling'** system will consequently be embroidered, knitted, multi-layered or woven throughout clothing. These particular fabrics have the intelligence to read emotional behaviour - which is the key part of the interaction - enabling fabrics to detect and document biomedical information as well as releasing pleasant odours. Many contacts have been developed with International technologists & Scientists who have proved to be an inspiration to the growth of the research (Refer to Appendices on page 137). Interactive textiles, therefore, begin *living* - only when cabled with technical expertise in micro-electronics - as a form of communication. Consequently, this new system will 'interact' by emulating aspects of biological events in garments of a radical design. This is discussed in Chapter 4 on 'Fragrance Delivery'.

1.5 The Wellness Collection

Smart System

The *visual* inspiration has been centred around the *'Our SMART System'* - the human body and its organs. The methodology of documented research marries the human body with miniaturised technology in the form of 'invisible clothing'. This represents the *fabrics heart* as an internal 'pump' and the *human nervous system, capillaries and veins* as the 'tubes'. Figure 4 illustrates a knitted 'therapeutic' structure whereby the heart represents a 'pump' used to 'pulsate' fragrances or medication (illustrated in a bottle) through tubes, which are integrated into fabric of clothes, and out through the surface. Subsequently, the evocative phrase - ***'THE WELLNESS COLLECTION'*** - has been devised to describe multi-sensorial approaches to the next generation of fabrics. This recognises that all senses will be involved and that interactions between major senses will be anticipated.



Wellness Action

The word *Wellness* has been allocated because nowadays being 'fit' isn't enough anymore. The goal to which we should aspire should be higher. The spirit of *Wellness* is much more than being simply '*not ill'* and is derived from well-being. *Wellness* as opposed to *fitness* is an approach to combating stress, comforting, reassuring, and boosting self esteem through *active* clothing. Every day we wear clothing which conditions how we feel for that day. This research concentrates on new fabrics, interacting with the skin and body condition to enhance and promote *Wellness*. The idea is that *Wellness* will come to you through smart fabric design.

Smart Signals

The SMART design will enable communication between body and fabric structure to take place automatically, ensuring a controlled fragrance delivery which is therefore not too over powering. These clothes will allow you to signal your emotional responses to a partner or friend. The implanted 'smartness' will also have the capacity to *read* the bodies physical and mental state and respond accordingly ie: - *through body movements, perspiration, sound, body odour, heart rate, emotional state, psychological state, blood pressure and breath.*

Smart Intelligence

As described in Chapter 7 on 'Smart Intelligence', fabrics with incorporated intelligence already have the ability to change colour through body temperature [1]. For example, they deodorise through micro-encapsulation, create light and sound with fibre optics and microelectronics and detect dangerous levels of pollution. Delivering 'smell' *intelligently, interactively* and *therapeutically*, however, has not been explored. The terminally ill and persons with distinct illnesses have specific odours. These will therefore be detected with 'olfactive intelligent fabrics'.

Nose-On-A-Chip

Current research is underway at various British Universities [2] concerning the complex second generation 'electronic nose' [3] which would possess exactly the properties required for the project. In the future there will be a miniaturised unobtrusive, minimally invasive 'fibre' nose-on-a-chip, fabricated into garments using *nanotechnology*. Chapter 11 will briefly touch on nanotechnology, although this vision is a long way ahead of us. The electronic nose will therefore be the real key interactive sensor system' for the PhD, documented throughout the thesis.

1.6 Summary In Brief

Triggering Science Fashion

A *science fashion,* multi-sensorial approach to contemporary design confirms the technology of *the senses* is the future of fashio*n. Wellness* is a *non-invasive* experience using miniaturised 'biosensing' technology, *'disguised'*, as the software structure in clothing. This enables *Wellness* clothing to have the capability of *mix 'n matching* different technologies. **The Triggers** & 'Inner-telligent Dermis' [4] described in Chapter 5 are responsible for switching a fragrance 'on & off', in order to control the release. Within the smart dermis and cabling system is the *brain power* or skeleton intelligence, controlling all information and commands from the body's behaviour.

[1] Using thermocromatic liquid crystal
[2] Glasgow University, Cambridge University, Warwick University, Birmingham University, Warwick University
[3] *Human nose* replica mimicking the olfactory system, using a computer as the 'brain'
[4] Research terminology for skeletal core of a smart fabric structure

Multi-Sensorial Nose System

Interactions between major senses can be anticipated - *sound - vision - taste - touch and smell* - which is the key concern. The *'science-fiction'* novelty incorporates individual *interactive smell delivery systems* within the structure of fabric and clothing. This can be personal (an individual interacting with their own garments) or on an intimate level with a partner (garments worn by two individual persons who interact accordingly).

Positive **Wearing**

This is an investigation into new areas of human behavioural conditions using '*smart fabrics'* which respond to individuals emotional feelings, by helping to manage/improve their lives better than is usual. It is vitally important for this research and is about wearing a new positive state of physical, mental and social health. Previous studies in Positive Wearing include NASA and flight gear.

Re-Cabling **Revolution**

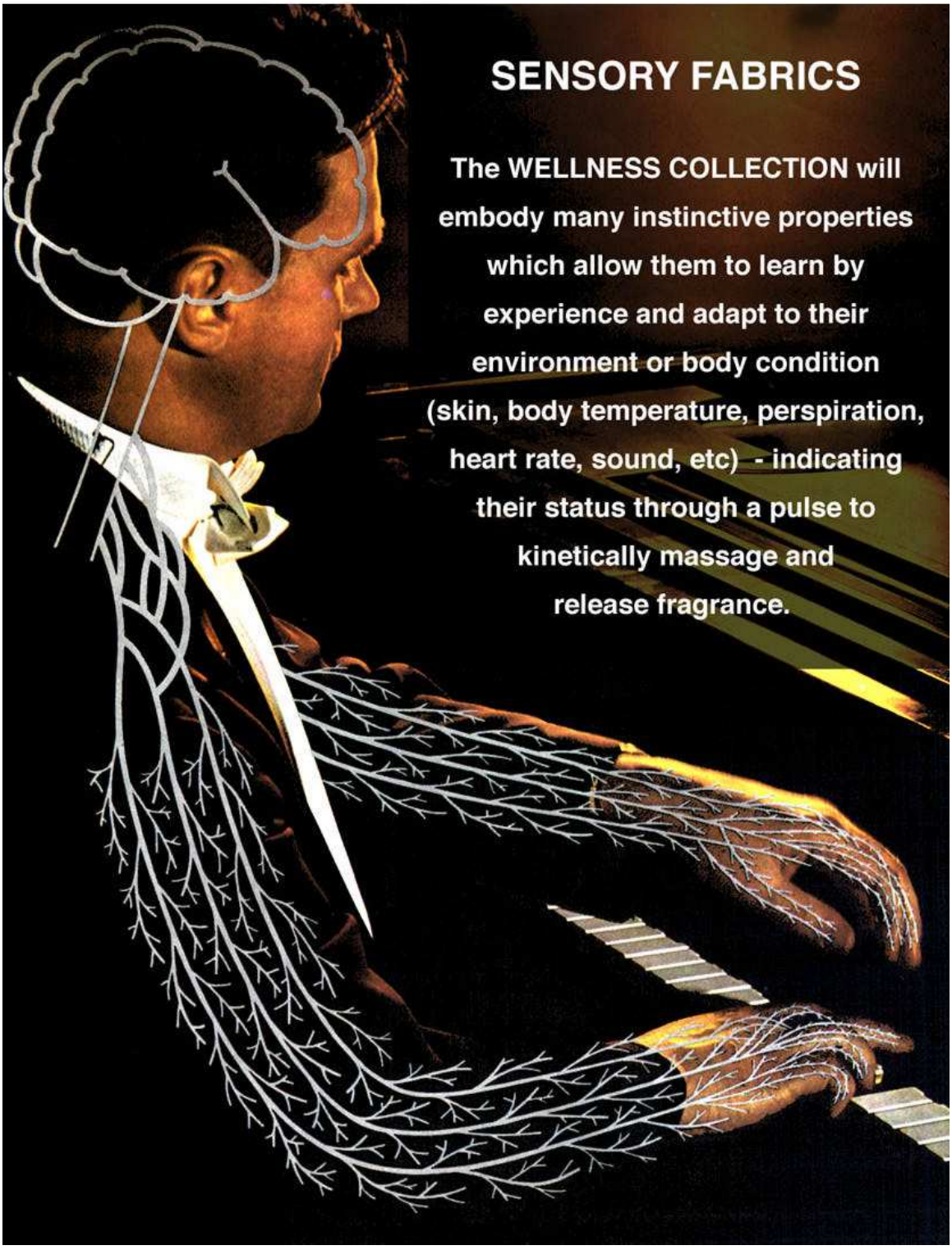
The '*Wellness'* philosophy and '*re-cabling'* technology is the beginning of a long-term project. Delivery systems and tubes (once fully miniaturised) will be functionable, therapeutic and pleasurable, utilising *the senses* to trigger and provoke experiences and memories. **The Dynamic Surfaces** & Outer-shell Dermis [1] described in Chapter 6 are comparable to a *living fabric* which is active, reactive, kinetic, visually aesthetic, stimulating and imitative of the living tissues of human skin. By researching the purpose of modern textile technologies and comparing this with *skin* (and other areas of the body) a *dynamic surface* will be created by integrating the following materials : - *Micromachines, Medical tubes, Reservoirs, Pumping Devices, Fragrances and Biosensors.*[2]

Therapeutic Wellness

New '*Wellness'* textile technologies will create a total ***'multi-sensorial smart fabric'***. They will reduce anxiety and stress by *kinetically* moving as a result of the smart structure (fig.5). Fabrics will change colour digitally, as calming smells or therapeutic fragrances (combining the alternative method of Aromatherapy) are released through delivery mechanisms, allowing fabrics to heat and cool, depending on the bodies temperature. Present research on transdermal drug delivery patches and Medical Textiles as discussed in Chapter 11 will contribute towards *The*

[1] Research terminology for protective skin surface to the smart fabric
[2] Analytical device converting concentrations into an electrical signal via a biological recognition system

Wellness Collection, to soothe, relax, stimulate, energise, arouse and control a selection panel of different fragrances for the appropriate 'triggered' moment.



1.7 Conclusion

Transporting *smell* is a much more complex process than simply concentrating on the mechanics and electronics of *pulsating* delivery systems. This research is dealing with 'known' technology and miniaturising systems, which can easily be woven, knitted, embroidered or implanted into new fabrics. However, difficulties arise with chemical issues relating to all discussed areas including evaluation, chromatography [1], the compatibility of tubing and micro-machine materials, thresh hold timing and fabric and fibre compatibility. These have not been fully pursued. The desire is therefore to enhance health and human behaviour, contribute and widen existing knowledge, fashion, textile and perfumery industries, by bridging them closer to Medical Science.

The most helpful, informative and stimulating conversations have been with scientists, engineers, trade shows specialists and doctors. One particular company is Ensyma Engineering SA from Switzerland [2] who have contributed towards the research experiments. It is through this valuable contact that the fortunate opportunity arose to meet Dr Andreas Manz [3] from Imperial College London. He has also shown a particular interest in the long term potential of this project.

[1] Method of scientific analysis and calculation in chemistry - and perfumery
[2] Experts in micro and nano-fluid machines for controlled drug delivery systems
[3] The Head of Analytical Chemistry and Chair to Zeeneca/SmithKline Beecham

Chapter 2

2 Multi-Sensorial Surfaces

2.1 Introduction

Sensing Sensitivity

In the second chapter all five senses and skin sensitivity will be under focus, but in particular *smell.* Taste and touch follow shortly afterwards - as they too are sensitive to the human skin (as opposed to hearing and vision which have no connection with the skin). It is vital to show the importance of the *multi-sensorial* interactions of the senses with each other, since this is the purpose of futuristic smart surfaces (and consequently why taste is not relevant to *Wellness* fabrics).We can also learn much about *pheromones* and the kind of effects they may have on men and women by reading about odours and their effects in other animals and in the records of ancient and past cultures. Finally, further references will combine the mystery and wonder of the sensory 'mix-up', *Synaesthesia* [1].

Multi-sensorial Action

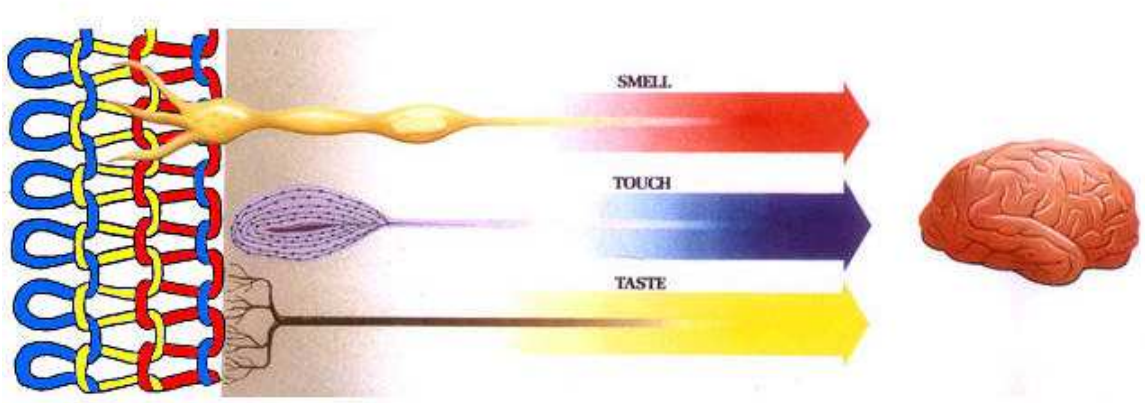
Non-invasive therapy and minimally invasive diagnostic *multi-sensorial fabrics* are based around the human body. There are 50,000 million cells in the body - some of which are the receptors used for 'the senses.' These send messages to the brain, which in the case of *Wellness* fabrics is the *'brainy'* software structure. Surrounding environments such as smells, images and sounds 'switch on' and feed the receptors so that the human brain - as well as *Wellness* fabrics - have the capacity to increase *the action* and improve life.

The Senses

The only link our brains have with the external world is through *the senses.* Without them we would be comatosed and threatened by total chaos. Figure 6 illustrates **'Sensorial Knitting'**, which is 'triggered' by information received from the body and brain. Sensory nerves gather information from the outside world, which is then decoded, sorted and filed to the brain. Acting as the body's computer, messages are sent out along nerves in the spinal cord to tell organs and muscles what to do. The intricate nerve network in our sensory system is a web of electrical mechanisms that make up the five senses – *sight, hearing, taste, touch and smell.* Sight and

[1] The sensory 'mix up', for example hearing in colour or tasting shapes

hearing work by detecting light and sound given off by objects that are not in direct close contact with us. Taste, touch and smell work differently, being embedded in the skin, feeding information to the brain or nervous system. When a message arrives at the body surface it triggers one of the many receptors waiting to detect important signals which are then turned into nerve impulses.



2.2 Smell

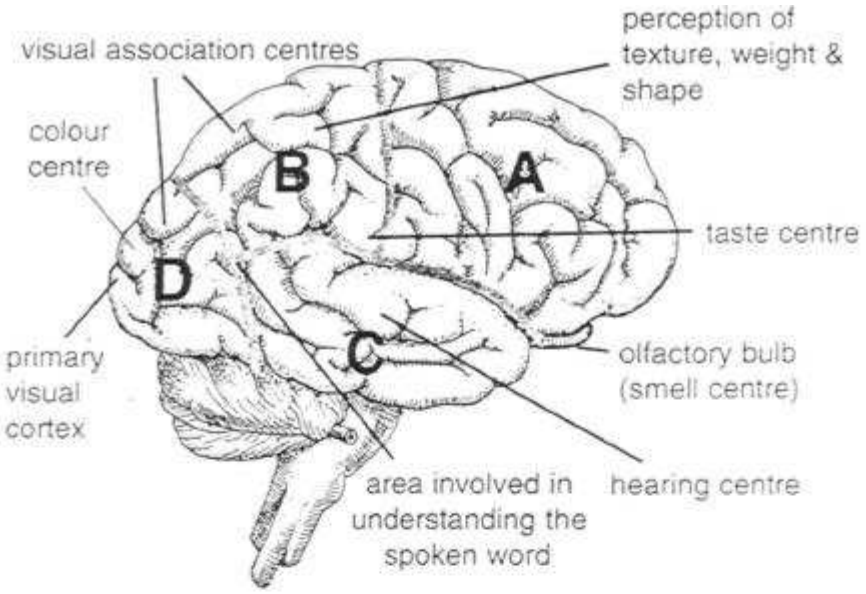
"We breathe all the time so therefore we must smell all the time." **Dr George Dodd** (ref 4).

We live in an audio-visual world. Smell is an exquisitely sensitive sensory system. Our sense of smell is now thought to be much more important for our health than was realised ten years ago. Life literally begins with smell - as we form a bond with our mothers, called an odour canon - and since smell signals have a direct access to the emotional centres of the brain the emotional shading of our lives is influenced by the smells around us.

The Chemical Senses

Like taste, smell is a chemical sense and far more complex than the others. It is incredibly sensitive (although nothing compared to a dog's sense of smell, which has 100 million olfactory receptor cells compared to 5 million in humans) with only a few molecules from 'the odour' required to arrive at receptor cells to trigger the cell to convey a message to the brain. The sensory signal travels along a short nerve fibre, by the olfactory mucous membrane and bulb to the olfactory region of the brain, creating the smell "image". The odour can come from a flower,

a memory or place, a person or a time, an olfactive evocation, or alternatively, an aggression (alarm signal), a fear (warning signal) or danger - from which the sense of smell appears principally to have evolved. Figure 7 illustrates the olfactory bulb in the limbic system and other lobes that control *emotion* and the 'senses'.



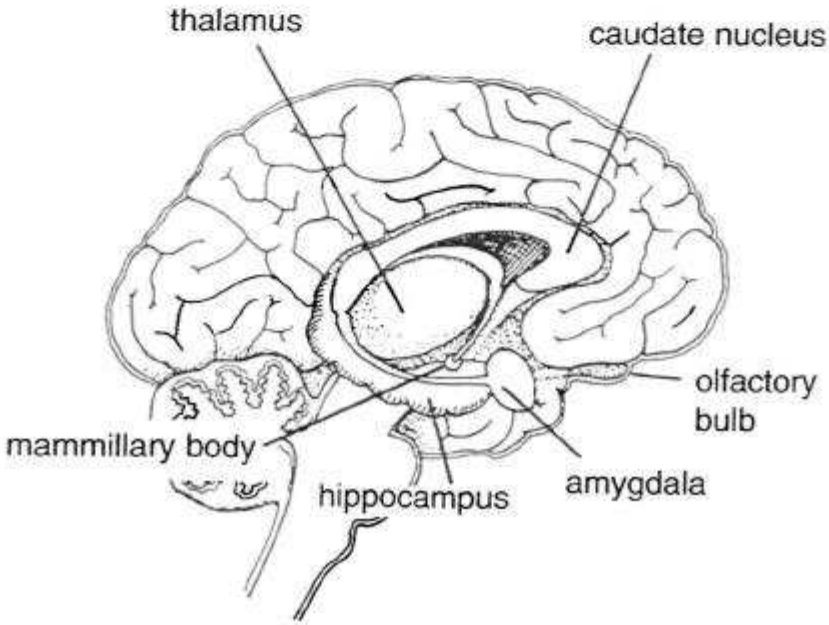
The cerebrum

A - Controls speech and is associated with our emotions and the control of our moral and ethical behaviour

B - Analyses information from our senses, processing data necessary for us to be aware of our bodies and its relationship to its external environment. Parts of this lobe allow us to appreciate texture, weight & shape.

C - Controls our sense of hearing, emotion, memory and is responsible for detecting movement.

D - Controls our appreciation of the written and spoken word and gives us our sense of sight.



The *limbic system* contains the olfactory bulb, responsible for our sense of smell

Memories

Research into the way we smell has revealed that the olfactory system directly targets the rhinencephalon [1] , which deals with emotion in the brain. This system also plays a significant role in selecting and transmitting information between our short-and long-term memories. Smell stimulates the memories and can be of great benefit to the elderly, especially those with Alzheimer's disease. It brings people out of their shells and gets them to interact.

[1] Limbic 'smell' part of the brain

The Ocean Within Us

Not only do we owe our own sense of smell and taste to the ocean but we smell and taste of the ocean, hence the phrase - *Our veins mirror the tides.* (ref 5) A human woman's ovaries house the eggs which lie like fish roe entering the smooth, undulating womb of the ocean from which our ancestors evolved millennia ago. Our tears are salt water and blood, too, is mainly salt water, which accounts for the popular fashion of 'sea inspired' fragrances such *L'eau Issey.*[1]

The Nose Leads The Way.

Every human body is an odour signature (ref 6) and body scents influence our social and sexual behaviour. Our perception of odour is influenced by our body chemistry, sex and age with odour only developing at puberty. The bodies own chemistry is the greatest sexual attraction, varying from day to week with different interactions occurring. The Chinese and Japanese population invariably have weaker body odour, due to less body hair and fewer scent glands (although this is now changing due to alterations in their meat-eating diet) On average the Japanese prefer to scent their homes more than their bodies.

Deja vu

Smells spur memories, help define our self image and drive our emotions, evoking memories from the past. Smells arouse us, e.g: - to emotions of fear, sadness, loss, love, disgust, longing and passion, buried deep in our sub-conscious, waiting to come to the surface with a single sniff. We fear and 'smell' nervous perspiration and talk of having a nose for danger. We are aware of smell, but do not automatically react in certain ways, as most animals would. Some animals exude a distinct odour as a form of self defence or deterrent. Soldiers in previous wars claim to have the animal-ability to 'smell' their approaching enemies. Unlike animals who spread personal odours around, however, humans deliberately disguise personal odour with scented beauty products.

Smelling '*Words'*

Smell is a communication vehicle. Descriptive labels cannot fully describe what happens when olfactory receptors and cells are stimulated (fig.8). Smell is well known as the *mute* sense because it is hard to describe smells in 'words'. The brain needs to be constantly reminded that there are smells around, hence the wonder behind the controlling mechanism of *Interactive Olfactory Surfaces.* Baudelaire, the French poet, wrote of mistresses, remarking that the essence

[1] Issey Miyake's first fragrance for women

of our souls resides in our erotic sweat. Odour was to Baudelaire what music was to others, and the Kama Sutra tells of the perspiration of the ideal woman. When the Germans detest someone they tend to say "Ich kann ihn nicht riechen" (meaning "I can't smell him", or “He stinks”). The French also say "*Je ne peut pas le sentir"*, which translates as "I cannot smell this person" but really means *I do not like this person at all*.

Skin from the nose is seen in section, showing tissue in the nasal cavity where olfactory cells are located (purple). Beneath, the layer of connective tissue contains nerve fibres blood vessels & glands.

The Sense Of Smell

Fig. 8

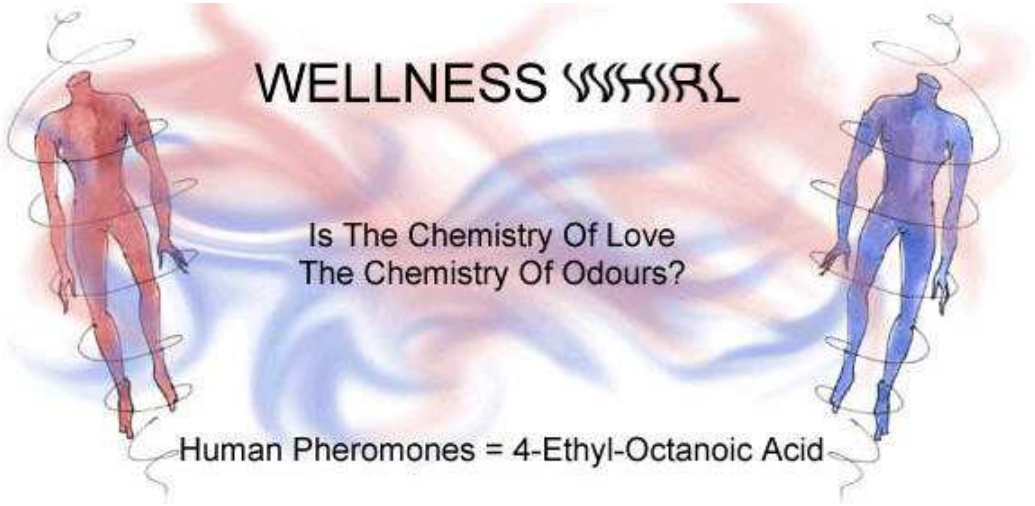
Smell And Sex

Casanova would remark on the odour of the woman with whom he made love. Joris Karl Huysmans, the Parisian novelist of the last century, contended that the hair of a woman had a whole gamut of alluring odours "that easily uncages the animal in a man". Others have celebrated the pleasing odour of armpits and breasts, both male and female. French prostitutes would dab vaginal fluid behind their ears to help waft their 'wares' to potential customers. In the 1960's, the English Physician Alex Comfort discussed human pheromones in science fiction books and papers before he became famous for writing 'The Joy of Sex'. This fiction is now becoming fact,

as scientific data confirms that humans have many of the sensory and neural components other animals use to detect *pheromones.*

Interacting Pheromones

Humans also produce pheromones. Current research forces us to look at our sexual behaviour - dancing is no longer just dancing, nor is kissing just kissing as both are ways for partners to share their natural body odour, serving as a sexual lure. Pheromones are still a big issue with Journalists, who tend to either over hype or confuse their mystery. In brief, pheromones are chemical messages produced by one member of a species that influences the physiology and behaviour of another member of the same species. Whether or not this chemical message is consciously detected *(through smell)* pheromones still have the same effect. (fig.9)



Social Odours

Mammalian pheromones, in the form of "social odours" that one member of a species is exposed to during interaction with another member, cause changes in hormone levels and in behaviour. Odours, genes, hormones and neural circuits interact together to produce several different behaviours and effects, at different times, in different degrees and in different parts of the brain. Since humans share many of their biological systems with other animal species (because we are animals) it seems logical that the sense of smell probably plays a much larger role than we commonly think in human social interactions, sexual attraction, sexual arousal, mating, bonding and parenting.

Pheromone Perfumery

Pheromones from some mammals are quite effectively used in perfumes such as civetone [1] , castoreum [2] and musk.[3] Every single body has a personal ' odour signature' as distinctive as our fingerprints, voice and personality. Sweat glands lie deep in the dermis and spiral through layers of horny epidermis cells - out of a tiny pore. Not only do these glands in the dermis predominantly produce salty fluids but, more interestingly, pheromones from the modified scent sweat glands, aiding sexual attraction. In humans these are located in our armpits, navel, genital and anal areas. Perfumes inspired around the concept of 'pheromones' include *Realm (USA), Philosophy* and *Pheromonal Factor* (UK). Dr George Dodd is working on a futuristic fragrance, concocted from components to enhance our own body odour signature. Perfumers have already identified 50 elements although there are many more to discover.

2.3 Taste

Bitter Sweet

Unlike smelling 3000 odours, we are only capable of tasting four basic flavours : -sour, bitter, sweet and salty. Our sense of taste is about 10,000 times less acute than our powerful sense of smell. When we prepare a wonderful meal it is usual to believe that we have created numerous 'tastes', which is simply not the case. In fact the odours add up to the four taste sensations and each of the 1000 taste buds, lying in the cracks of the tongue and throat, has up to 30 receptor cells leading to the brain**.** (This related to chemical properties and the bombardment sensitivity of molecules, gives us the sense of taste). 90% of taste is smell and sadly man is a poor taster compared to a cow who has 90,000 taste buds! But in a culinary way eating exerts a whole symphony of sensations on our sensory organs.

[1] Fluid secreted by Ethiopian civet cats or a synthetic product used in perfumes
[2] A secretion from the beaver or a synthetic used in perfumes
[3] A greasy secretion produced by deer's musk or a synthetic used in perfumes

Artificial Taster & Edible Textiles

We see food with our eyes, smell its flavour and feel the temperature. Sensory cells which detect taste have a short life span and to date technology has found it difficult to create a tasting machine - like in 'the electronic' form of artificial smelling**.** The concept of edible surfaces [1] and textiles is at present totally unuseful and uninspiring, but if and when developed further - 'wear and eat' textiles *could* have serious implications for survival and military purposes.

2.4 Touch

Tactility

We have a very acute tactile sense which - like smell - is put to use from the first hour of life. There are several different touch senses, each with a different type of receptor embedded at a different level of the skin. They are sensitive to either pressure, temperature, pleasure, sexual contact, tickling and of course pain. If these are unpleasant or dangerously intense it could threaten our survival. Nerve endings in the skin detect these factors and signal to the brain to move away. After an initial burst of touch sensation activity the receptors calm down to a lower level of activity. This explains why we are unaware of the feeling clothes have on our backs and concentration strays elsewhere. The Chinese consider their second skin to be their lungs, which represent the centre for breathing and are so important to life.

2.5 Hearing & Vision

Sound

Vibrations are sent out as waves of air pressure. These are too weak to be felt by the human skin and so we use our ears to 'hear'. The waves of air pressure heard in the ears are sound-waves. In Wellness clothing a multi-sensorial 'sensor' will eventually be the ear to detect what is happening in the surrounding environment.

1 Edible lingerie and cake-making rice paper

Vision

Our language is steeped in visual imagery, which happens with our brain and not our eyes. However our eyes have mechanisms which gather the light, pick out an important novel image, focus it precisely, pinpoint it into space and follow it. Our eyes must be bathed in salty water again, reminding us of our oceanic routes, used as a protective layer for muscles to gather light.

2.6 Synaesthesia

The Sweet Smell Of Purple

Synaesthesia is a sensory mix-up or confusion in perception of the senses which was only diagnosed 300 year ago. (ref. 7) A person with this particular disorder - or in some cases it can be referred to as a *creative gift* - is called a Synaethet. The painter, Wassily Kandinsky and the author Vladimar Nabokov were ruled by synaesthesia throughout their lives which obviously proved beneficial to their works. It can, however, be a very frightening experience- whereby sight and sound intermingle (coloured hearing) and touch and taste run together- as well as a very sensual tactile and emotional one. Music causes a brilliant vision of shapes, numbers appear as an array of colours, and more commonly, each letter in words are made up of different colours, creating a mass of spectacular splendour for speech and the thought process. (ref. 8). Another example shows an American Synaesthet religiously judging his food by *its texture and shapes,* ie: chicken might be too *pointed or prickly* in answer to a taste related query.

Sadly, throughout the research it has proved impossible (so far) to track down a *smell synaesthet*, an extremely unusual variety for synaesthesia - but one which is no doubt valuable to the future of this project.

2.7 Conclusion

The sensory aspects of skin, and in this case fabrics, subsequently introduces the concept of a living fabric of the senses, which is *active, reactive* and sensitive in every possible form.

Contrary to what people might think, smell is the least researched of the senses but the most appealing and powerful. The following chapter concentrates on perfumery and the importance of CoCo Chanel in the 20th Century, who revolutionised both fashion and perfumery industries.

Chapter 3

3 Perfume Revolution

3.1 Introduction

In Brief

The background historical chapter on Perfumery will be as brief as possible, due to the complexity of the subject. It is called *'Perfume Revolution'* due to the impact caused by CoCo Chanel on perfumery in general, at the beginning of the century (fig 10).

International Flavours & Fragrances (IFF)

Before embarking on the PhD, in November 1994, it was essential to visit major Fragrance Houses. Throughout the MPhil programme contacts had already been established with

International Flavours & Fragrances Inc [1] in the UK so it was important to visit the French headquarters in Bois Colombes, Paris and meet professional perfumers at work [2] . The following year, an opportunity arose to visit International Flavours & Fragrances in the USA [3] and present progressing research-based visual concepts to Marina Munteneau [4] who was fascinated and encouraged by the futuristic and charming possibilities for interactive fragrance '*smart'* clothes.

Revolutionary Perfume

Throughout the research a number of other professional perfumers at competing International companies (ref 9) have had the opportunity to contribute to and discuss the seminal ideas being explored - as well as Aromatherapists, [5] AromaCologists [6] and Biochemists. Evidently, throughout the course of the research we are lead to believe that the overall vision behind re-cabling clothing for fragrance release in smart fabrics *could* lead to a revolution in perfumery, which would no doubt be similar to the important relevance of CoCo Chanel and her *No 5* fragrance. She - as a fashion designer - made *perfume history* in 1921.

[1] An International leading Fragrance Company
[2] Monsieur Jean-Pierre Mary
[3] IFF Research & Development Centre, New Jersey
[4] Vice President & Director of Fragrance Technical Development, New York
[5] Alternative therapeutic treatment enhancing well-being using essential oils
[6] Scientific back up for modern perfumery

Musical Perfumery

Perfume means to 'smoke through' and is the creative result of the perfumer, realised with an accord of 'olfactory notes'. (ref. 10) It is rather like composing music with the top, middle and base notes. A fragrance, as opposed to an odour which can be agreeable or disagreeable, is of Latin origin and normally indicates an agreeable odour emanating from a perfumed product. It is a symphony written from the following eight groups of raw materials : *Vanilla/powdery, Woody-mass, Spicy, Fruity, Green, Floral, Aromatic &.Hesperidic*. (fig. 11 - 'scratch and sniff').

Above all a fragrance is an essence, but beyond the subtle fragrance an imaginary world emerges.

Chapter 3 - Perfume Revolution 19

The *Scratch n'Sniff* Fragrance Palette

Aroma Chemicals supplied by Quest International UK

Aroma Encapsulation by 3M UK

fig. 11

Interactive Olfactory Surfaces

The Interaction Of Flowers

International Flavours & Fragrances accidentally discovered that two flowers growing side by side did not only give off their individual two smells but created a whole new scent between them. This has been labelled *the emotion of flowers* and Elizabeth Arden has subsequently called one of her fragrances *True Love,* created through the pairing of lotus and narcissus.

3.2 The History of Perfumery

Influential Perfumery Power

The belief that certain aromas have the power to influence our emotional state dates back thousands of years. The Oracle at Delphi inhaled smoke from burning bayleaves to induce a trance-like state, the Greek herbalist Dioscorides noted the soporific effect of myrrh and marjoram and the earliest civilisations believed burning aromatic woods and herbs would drive 'evil spirits' from people's minds. Aromatherapy is now used to combat psychological problems such as stress, anxiety and depression with convincingly popular results.

Magical Potions

The ancient practice of using aromatic substances to uplift the spirit or cure diseases has been used by the world's greatest civilisations throughout history. Uses have included the art of creating ointments, medicated oils and *magical perfumes* designed for love. Perfumes were used by the Ancient Egyptians in religious ceremonies (as Buddhists and Catholics burn incense nowadays), by way of burning fragrant wood and essences to please their gods. The Greeks were the first to use liquid perfumes, despite their association with the pleasure of love which was offensive to the Christian movement. The Crusaders reintroduced the art of perfumery to Europe in the 11th century. Following the 17th and 18th centuries, perfumes were used in other ways - as a mask for

unpleasant odours, caused by lack of personal hygiene. After the French Revolution, major perfume houses were first opened in Paris, however in 1729, the perfumers of Grasse [1] were awarded status and even to this day, the region still remains influential in the fragrance Industry.

The Synthetic Age

The 19th & 20th centuries saw the greatest changes of all with the achievement of chemical synthesis, giving the perfumer new notes and a veritable symphony of smells to play with. Since the middle of the 19th century, during the "Olfaction Revolution"[2], worked on synthesising the natural essences of perfumes, that is, to manufacture in the laboratory the scent of the carnation, rose, lavender etc. The aim was to stabilise the supply of ingredients and to enlarge the manufacturing potential of perfumes by lowering the cost of materials. One hundred and fifty years ago a revolution occurred in perfume, enabling a limitless range of notes to be synthetically manufactured - divided into 2 groups - those imitating a natural scent - and totally new scents unknown to nature. [3]

Perfume Industry

The larger perfume houses in Paris, who tend to be connected to Couture Houses, spend around 5 million pounds each year synthesising molecules, the vast majority of which will never be used in products which reach the high street. 2,000 to 3,000 molecules are designed by perfumers from which maybe two will eventually end up as the final perfume ingredients for major success stories.

3.3 The Chanel Century

CoCo Chanel

Even for those who do not care for fashion and fragrance a historical glance at the 20th century which ignored one of the most influential women, Gabrielle Bonheur (CoCo) Chanel, would seem incomplete. (ref. 11). She was one of the first to recognise the consumer's need to *belong to*

[1] A region in France with historic roots in perfumery
[2] A term used to describe Paris.. by Alan Corbin
[3] Floral and plant extract fragrances and secondly synthetic fragrances

a trend as well as the importance of diversification for the future of her business, by designing its clothes and creating an independent style. This still remains a standard statement of contemporary elegance, borrowing themes from understanding menswear. She successfully combined military logic with stunning creativity and the classicism of English chic and comfortable tweed jackets.

Simplicity

Her first successful designs, which displayed a preference for simple lines and plain cloth, were known as the 'poor look'. Chanel's approach - "*less is more"*, in combining military traces of gilt and chain with simplicity and attention to detail, was - and still is - widely copied internationally.

The Magic Number CoCo Chanel 1921

"A woman should smell like a woman, not a rose. I wanted to give women a perfume that was artificial, exactly in the way that a dress is artificial, that is man-made. I'm an artisan in dress-making. I want a perfume that is a composition" (ref. 12)

No. 5

In 1921 Chanel wanted a unique and sumptuous 'couture' perfume, something that reflected the essence of her style. Her fragrance would therefore ignore boundaries and conflicts, by utilising modern and synthetic smells (as opposed to the usual naturally floral notes of rose, lavender or jasmine). This was an extraordinary concept for that time, as modern in its thinking as the work of her painter friends, Picasso and Dali. Between 8 & 10 versions of totally original fragrances were composed for her by the great chemist Ernest Beaux.[1] He used 80 components and boldly introduced high concentrations of chemically synthesised aldehydes [2] to enhance the odour for the very first time ever. Mademoiselle Chanel sampled them all and chose the strongest jasmine smell as well as the one containing more than 24 components, the fifth - *the magic number*.

20th Century Revolution

There is a mysterious source of youth in the image of No 5. Not only was the new fragrance proving revolutionary but the plain packaging and bottle (a bold, rectangular crystal shape) were inspired by convenient 'handy travel bottles' and a complete change from the previous pearlised

[1] A Moscow Chemist who worked for the ballet and was a master perfumer.
[2] Organic chemical containing carbon, hydragen, & Oxygen atoms derived from natural or synthetic material

bottles. It kept with the unfussy style of her designs, and so the major revolution of the 20th Century was making history for the big fashion statement. Clothes with new fabrics were becoming shorter, simpler and less frilly, bearing the new uncorsetted modern woman.

3.4 The Smart Sense Century

Sexless Scents

Modern perfumes of the nineties are flirting with sexual equality (ref. 13). Manufacturers are making perfumes more 'masculine' and 'aftershaves' more feminine as values are being redefined and fragrances need to constantly reflect the lifestyle of the new man and woman. The androgynous or cross-dressing scents, *CK One* from Calvin Klein, launched in 1995, and the recently launched 1997 fragrance CK B are closing the gap between the macho nasal assault of after shaves and delicate eau de parfum.

> Steve Van Toller, Director of the Olfactory Unit at Warwick University says:
>
> **"They are now creating perfumes and after shaves for people who don't want such clear distinction in what they wear".** (ref. 14)

Cross Dressing

At £20 for 50ml, Calvin Klein's *CK One* is cheaper than the average price and pitched to appeal to both sexes. This can, of course, seem increasingly confusing as well, since results show that what constitutes male and female fragrances is far from clear (ref. 15). The idea of a scent belonging to one gender is growing outdated, according to Roja Dove, Professor of Perfumes at Guerlain, a French fragrance house not connected to a Couture house, 60% of perfumes are bought not for their smell, but for the image portrayed in advertising. However Chanel, the classic grand perfumer, dismisses the idea of 'shared fragrances', proclaiming that they are not at all affected by young trends.

Fragrance In The Nineteen Nineties

From 1992 to 1996 the total world market for fragrances increased by over 17%, reaching to reach US$18.2 in 1996 (ref. 16). Line extensions and relaunches have been a major feature of the women's market, including extensive advertising campaigns to promote brand awareness. 1996 proved that eaux de toilette is now being challenged by eaux de parfum, although it still accounts

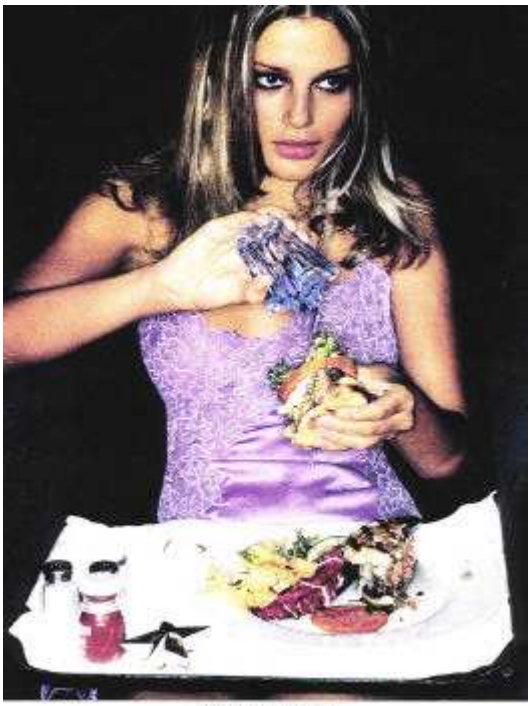
for 30% of the women's fragrance market. Key markets are experiencing a distinct trend towards eaux derived from plant extracts as opposed to non-perfume based products resulting in dramatic eaux fraiches [1] sales.

Nineties *Food - Fragrances*

There are fashions in perfumes as there are in clothes. Each era has its favourite smells - *a whiff* of what evokes the beauties and charms of each succeeding age. In the Nineties a new partnership of perfumery and science has developed as perfume companies employ *sensory psychologists* to work alongside *traditional noses* due to the explosion of fragrances and their apparent effect on the wearer's state of mind. Many perfumers composing perfumes have decided that the consumer is looking for comfort and reassurance, for fragrances rich in notes guaranteed to remind us of childhood.

Food Is The Drug

Thierry Mugler, for example, has abandoned traditional floral notes and replaced them with warm, comforting honey, caramel, vanilla and chocolate smells, for his first 'food inspired' fragrance called *Angel.* (fig 12). Vanilla is addictive because of its milkiness, a firm favourite with many contemporary designers, such as Calvin Klein who used large amounts in *Obsession*



Angel Food By Thierry Mugler
FIG 12

1 Fresh fragrant water
2 Key Impact Odorants

Drug Behaviour

Comme des Garcon launched their perfume by promoting - *'it works like a medicine and behaves similar to a drug'*. *Poeme* contains narcotic ingredients - flower from desert. Is there a danger of perfumes becoming so effective that they come to behave as drugs? Scientific papers, indeed, have proved that the effects of certain fragrance ingredients on neuroreceptors in the brain are similar to those created by drugs.

Key Impact Odorants

Dr George Dodd says that if we are to understand the psychological impact of food aromas in perfumes it is necessary to take an approach that focuses on molecules known as KIO's.[2] These a are relevant to the the human psychology of smell, though scientists are still unsure why we are so sensitive to these molecules.

Dr George Dodd suggests that : -

> *'Our brains have a set of receptors, possibly originated in the hunter-gatherer phase of evolution, which effectively pick up faint traces of KIO's, the vital clues to a source of nourishing food and so generate the psychological comfort we associate with feeding'.* (ref. 17)

Computerised Perfumery

According to Dr Luca Turin, Scientist at University College London (ref. 18) and Consultant for Quest International,[1] perfume designed by *computers* could soon become available, able to predict how particular molecules would smell. This development reflects recent research that will allow scientists to create smells through the vibration of molecules as opposed to the trial and error method of fragrance creation currently used by perfumers. This relies on recent research relating to the brain reading smells, by vibration of molecules as opposed to perfumers' current trial-and-error creation of smells. Turins system will be able to develop new molecules and work out exactly *how* they will smell before any perfume is made, saving companies alot of money, not only in perfumery but in other industries too.

3.5 AromaCology

Headspace Technology

"Aroma-cology" was introduced in 1987, after the first International Olfactory Conference at Warwick University [2] . This described the science devoted to the study of the relationship between *psychology and fragrance.* Its purpose is to elicit various feelings and emotions, using *headspace technology* - in which it is possible to analyse and synthetically reproduce odours given off by almost any element, anywhere you go, recreating that *wanted* smell in a fragrance and allowing a new palette to take shape. Donna Karan's fragrance **DK Men** used *headspace* to suck out the ambience of Nat Sherman's famous tobacconist on Fifth Street, New York, as well as raw, oily essences from racing cars. J del Pozo's fragrance **Quasar** used *headspace* to capture smells of financial newspapers - perhaps a way of signalling that you work in the city.

[1] A subsidiary of unilever
[2] Warwick Olfaction Research Centre

Temporary Smell

Unlike *aromatherapy* which has no science to back it up, aromacology is concerned only with the temporary effects of fragrance on feelings and emotions and not the therapeutic effects on mental or physical conditions. Aromacology is a rigorous science dealing only with effects achieved through stimulation of olfactory pathways in the brain. It measures the effects of blends of odorants and single natural and synthetic odour materials.

Brain Olfaction

Over the past 10 years a substantial amount of research has been conducted in the US, Europe & Japan to measure the effects of fragrances on feelings, emotions and moods as well, as electrical activity in the brain, physiological parameters such as heart rate and skin conductance, cognitive functions and voluntary and involuntary behaviour. The idea that different *smells* produce different behavioural moods is hardly new. In Japan aromacology AND aromatherapy are receiving considerable attention, especially companies including Kanebo, Asahi Chemical and Mitsubishi Rayon,[1] which will be discussed at great lengths in Chapter 4 relating to fragrance release in fabrics/clothing.

3.6 Aromatherapy

" . . . . . *the way to health is to have an aromatic bath and scented massage every day"* **Hippocrates**

Holistic Well-being

Aromatherapy is a therapeutic treatment which enhances well-being (or *'wellness'),* relieves stress, promotes good health and vitality and greatly complements other forms of therapeutic treatments.(ref. 19) The overall *Holistic* approach claims to be more efficient when used for the benefit of the 'whole person', both physically and emotionally. Records have shown that aromatic oils were used as far back as 3000 BC, possibly further. Hippocrates studied the medicinal properties of plants, noting extensively that burning particular aromatic substances offered some protection against contagious diseases. Aromatherapy emerged from its distant past at the turn of the century and is now widely accepted as a comprehensive natural therapy by most healthcare professionals.

[1] Japanese Companies researching into micro-encapsulated surfaces

Aromatherapy Oils

French cosmetic chemist Rene-Maurice Gattefosse was the first scientist to conduct a scientific study on therapeutic properties of *'essential oils'*. [1] Whilst concocting perfumes in his laboratory he accidentally burnt his arm and plunged it into the nearest cold liquid which happened to be lavender oil. He was astonished to discover how quickly the burn healed without scarring. This incident led him to devote his life to the remarkable properties of healing and it was he who was responsible for coining the term "Aromatherapy."

Applications

Essential oils are used by massage applications or inhalation. The oils are fragrant chemical substances extracted from aromatic plants (the exact scent of plants) using distillation, which preserves the therapeutic qualities inherent in the plants (through the roots, flowers, stems and leaves) whilst presenting us with a highly concentrated fluid more readily absorbed by the human body. Each essential oil claims to have unique therapeutic properties, useful in reducing stress, easing pain and digestion and stimulating circulation; some are antiseptics, anti-infectious and antispasmodic. Aromatherapy can particularly benefit problems relating to lack of stamina, skin disorders, poor digestion and aches and pains**.** It can also increase physical energy levels and facilitate feelings of relaxation.

3.7 Alcohol On The Skin

Chemical Warfare

Alcohol [2] has been used in perfumery since the 18th century. It is used as a neutral solvent in preparing fragrances and added to the concentration as a vehicle for the oil, modifying its intensity and making it easily applicable to skin. However, our skin was never designed as a vehicle to hold perfumes and alcohol based perfumes tend to dry it out, sometimes causing severe rashes and skin disorders.

[1] Fragrant volatile extracts obtained from aromatic plant elements using distillation, expression, extraction
[2] Denatured ethyl alcohol - 96% proof

3.8 Conclusion

Smart Smell Century

The 21st century will see the development of the olfactory sense and **OSMICAL FASHION** [1] (fig. 13a & b). As we experienced during the 20th century, technology has greatly lifted our standard of living. For the forthcoming century technology should also bring aesthetic and spiritual satisfaction, concentrating on the two ***'s'*** words : - smart and sense and consequently make the next century the *Smart **Smell** Sense Century.* According to George Dodd **OSMICAL FASHION** could be the next revolution in perfumery, the last one being Chanel's No.5. Biotechnology has already brought important scientific benefits to humanity and will continue to do so over the following decades. One day soon scent may control our moods, attitudes, likes and dislikes and help us find our perfect mate.

Alcohol Compatibility

At this stage in the research it can be anticipated that any alcohol-based perfume, integrated into micro and nano-machines, will inevitably 'upset' the mechanics and tubing systems(described in Chapter 8 on the Electronic 'Pulse') until the mechanics and electronics are correctly modified and evaluated with future Research & Development. The purpose of perfumery and the *Wellness Collection* is to design a vehicle for fragrance delivery directly *into* the fabric structure, preventing both a loss of 'sprayed' scent through an atomiser and any irritation of the skins surface.

[1] An adjective derived from the Greek OSMO (the science of chemistry or smell).


OSMICAL FASHION
The 21st century brings some startling possibilities for novel approaches in fragrance
One possibility is the design of interactive fragranced clothes
PARFUM
This is a new development which takes part of its inspiration from biology
N°5
CHANEL
PARIS
These clothes will allow you to signal your emotional responses to a partner
The SMART design will enable this communication to take place automatically

Delivering For Design

The novel objective for *Wellness* is to act as a new *smart vehicle* for the next century. Consequently, there are a number of different methods of releasing scent and other fluids, hence the following Chapter 4, "Fragrance Delivery."

Chapter 4

4 Fragrance Delivery

4.1 Introduction

Reviewing Scratch and Sniff

The kernel problem in any olfaction project is the classic one of *odour delivery systems* and which specialised direction to focus on. The novel part of the story is that interaction is of a primary importance, involving the literal incorporation of a new *delivery system* as part of the fabric. Throughout the early periods of the PhD it was necessary to visit as many factories, companies and research centres as was feasibly possible in order to stimulate the design process and collate substantial references relating to different areas of *fragrance delivery* available at the present time. This subject areas does not cover all the mechanical and electronic possibilities of future delivery aspects for fragrances and medication, which will be fully discussed in Chapter 8 on the Electronic 'Pulse'. However, it is important to stress - and constantly alarming to witness - the extreme lack of innovation in contemporary methods of fragrance release in fabric surfaces. By this the research implies the popular (although thoroughly uninspiring) method of micro-encapsulation. [1]

Examples Of Fragrance Delivery include :-

Micro-encapsulation

Environmental Odour Delivery [2]

Fabric Conditioners

Insectal Pheromones[3]

Micro-encapsulation

This is the process whereby tiny talc particles are surrounded by a coating made of small capsules with useful properties. Once the coating is broken, droplets release fragrances.

[1] Micro-particles for fragrance release
[2] Infusion devices used to emit odours into the atmosphere for enhancing or disguising odours
[3] The '*pencil*' – or delivery system in insects for signalling scented chemicals

Applications in this field have not advanced creatively for years, causing repetition and lack of vision. There have been no other avenues to choose from besides the method of *micro-encapsulation* in clothing - which washes out - and the lingering odour in magazine advertising campaigns. *Micro-encapsulation technology* tends to appeal to various Industries and Designers who cannot, as yet, visualise the inevitability of interactive miniaturised odour systems.

The objective of the project has been to completely *rule out* this unexciting, ancient method and move closer towards two particularly different areas relating to :

(i) *Inspiration from nature, biology & the human psychological condition.*

(ii) *miniaturisation of micro-electronic techniques and state-of-the-art research information.*

4.2 Odour Delivery : Biological and Non-biological

As *design-based* research, crossing-over into science, the original plan was (and still is) to emulate aspects of *'biological'* events in fashion garments of a totally radical design. *Odour Delivery* is the key objective with respect to the binding of different Odorants. In the case of the research - different fabric surfaces are the critical features for odour to be *adsorbed* too and subsequently ending with smell sticking to it. The key is ***odour versus time,*** as no odour level is required can be used which only which shoots up into the air and dies. It is consequently imperative to delve into nature and divide odour delivery into biological and non-biological systems.

Biological

This is frequently concerned with body odour in mammals (including humans) which are both **active and interactive.** Thus, an animal using all its *senses* will 'sense' biologically relevant odours which will lead eventually to activation, by 'pumping', of the odour glands - giving both qualitative and quantitative information. A biological system is clearly 'human' as it is undeniably *garment orientated* in its novel futuristic aspects. This again emphasises the multi-sensorial cross-over described in Chapter 1, and proves that <u>all</u> other senses can be enjoyed (colour changing, temperature, and 'sounds'). Secondly, it introduces the notion of 'squirting,

pumping or pulsating' a fragrance around a smart fabric - on demand. It literally imitates biological references to odour glands and consequently the magic of signalling scents occurs in a fabric, as it would in an animal or human being.

Novel Polymers For *Osmical* Fashion

The research therefore ambitiously aims to emulate aspects of these biological events in fashion clothes of a totally radical design - in which one of the primary functions of the fibres and fabrics, in additional to mechanical and thermal functions - is to act as a global, sophisticated odour communication system. There are two technical developments in polymers which are important for the future of the research ideas. One is the area of computer-aided design of novel polymers, generating some extremely interesting new ideas in the physics of polymers (ideas which would have a wide applicability in a range of industries). The second development involves a new and rapidly expanding area of electro-active polymers regarding the 'electronic nose', discussed in Chapter 5 - *The Triggers.*

Non Biological

This is exemplified by current passive perfumery on skin and clothing, including conventional perfume bottles, diffusion devices used in room freshners, micro-encapsulation methods (which is active but does not last), fabric conditioners with heat and passive non-active plastics. However, these are all *NON INTERACTIVE***.** Some action may be necessary to elicit the odour in some of these devices, for example *mechanical action* in the case of capsulated Odorants and *heat* in the case of some plastic odour matrices. All these are nevertheless relatively unsophisticated activities.

Odour Communication System

One of the primary functions of the fabrics and fibres, in addition to mechanical, *smart* and thermal functions, is to act as a *global, sophisticated odour communication system,,* something which is totally impossible using the old method of micro-encapsulation because :-

(i) There is no interaction or aesthetic beauty between the *other senses,* ie: it is only possible to activate an encapsulated area by *rubbing* away the surface to release the smell. It cannot therefore be called a '**living surface.'**

(ii) Temperature cannot be manipulated, monitored or controlled - limiting the choice

(iii) The life-span of encapsulated surfaces 'dies' down and cannot be regenerated.

(iv) Limitations do not allow *'smart'* micro-electronic-intelligence to work in the capsule.

4.3 Micro-encapsulation

Scratch & Sniff

This is the process in which micro-encapsulation manufacturers (ref 20) create tiny *talc* particles or droplets (which are invisible to the naked eye) surrounded by a coating (the container) to make small capsules with useful properties. Once the coating is broken, the droplets are released on fabrics, wool fibres or other surfaces (woven, non-woven, rubber, polymer forms and paper). The gradual release occurs through body movements or by rubbing away at the surface, commonly known as the 1970's method of *scratch and sniff.*

The oil in the core may contain : -

An emollient, lubricant, mineral oil, fragrance oil, sunscreen, aloe vera, colour producing material, micro-encapsulated insect repellent.

When dry, the microcapsules have a silky-smooth feeling similar to talcum powder for cosmetic purposes. An essence or aroma can therefore be encapsulated, *as long as the capsule is not broken..* This method is very versatile and will last for years without releasing its contents. [1]The rate of release can be further slowed down by fixing the capsules to the wool fibre and then covering them with a micro thin layer of resin, which also serves to make the fabric machine washable.

[1] Tiny capsules are 2-20 microns diameter

Colour & Deodorisation

In addition to fragrances, anti-perspirants and colours can be encapsulated. Light weight wool fabrics are particularly successful for this technology (ref. 21) which can also be added to printable ink, without affecting the colour or substance. Examples of this include disposable tissues, samplers, drawer liners, wadding, packaging, stationary, dental care products and bank notes. For example, some banks in the US *scent* money in automated teller machines

Perfumed Pearl

3M (UK) PLC claim to be the inventors, using their trade name *scratch n' sniff,* of a different resin capsule, binding and print process in 1984 for magazine sampling called 'fragrance burst'. [1]In 1992 **3M** *i*ntroduced the 'Perfumed Pearl' (ref. 22) technology for advertising industries. As opposed to the 'fragrance burst' capsules, powder in the pearl will remain in fabrics for up to 10 washes.

The **3M** 'slurry' process can be added to any vegetable dye and water base ink, yarns and threads for weaving using a translucent resin. The pearl method will 'fall off' fabrics in the powder form, when the capsule is broken.

ScentStrips & Sealed In Scent

The smelly strips in magazines are produced on lightweight web offset. Oil has to be encapsulated as above and becomes a 'slurry'. This method lasts no longer than six months, depending on the fragrance. *Scent Seal* (ref . 23) hermetically seal promotional samples so that they emit no smell until opened, resulting in a true rendition of the perfumed product in a moist form which can be applied directly to human skin. Although this is extremely popular, preventing pre-odour leakage is difficult and magazines may endlessly stink of stale perfume concoctions or aroma food advertising. The Director, Trebek-Kares, believes that the *aromacology* blend behind this technology will stimulate or calm the body and mind when used in fabrics. For example, microencapsules could stay intact and only release the perfume they contain when in contact with water. This typically would follow a period of skin sweating, for example when sport is involved.

[1] Capsules break once the page is ripped open

Polyiff [1]

International Flavours & Fragrances (IFF) are able to impregnate plastics with any given scent using a technology called **'Polyiff' –** used in scented toys and plastic bin liners. (ref. 24) These are ready capsulated little balls of plastic with an extremely strong smell. 'Swatch' watch once used fragrant plastic using IFF's 'Polyiff', which was a big commercial success. Since then, impregnating plastics with scent have not proved to be particularly popular or wide spread.

Addiction

A behaviour modification method exists in which *olfactory stimuli,,* comprised of a *patch* incorporating microencapsulated dominant and lesser Odorants, are released on scratching. This method is used for addiction, avoidance and substitution and can treat over-eating, smoking and alcoholism.

Japanese Technology

Japanese companies have been masters in the field of micro-encapsulation due to the obsessive intensity and desirability of their hygiene habits. Obscure applications range from marketable products such as over-night 'feel good' bras, gloves and pillow cases, containing moisturising properties and *fragrant* fibres developed and manufactured by world leading companies, eg : - Kanebo, Mitsubishi Rayon, Matsui, Asahi Chemical & Pigeonwill Corp.

Kanebo

Kanebo claim to be the worlds only integrated maker of the six major fibres - cotton, silk, wool, nylon, polyester and acrylic. (This is without a doubt, Japans most successful company,) having marketed a wide selection of '*feel-good'* micro-encapsulated products. In 1987 they released the highly popular '*good technology for legs',* developing fragrant support stockings, but it was not such a hit in the UK(ref. 25). Rich in minerals, Vitamin C, aphrodisiacs and seaweed extracts, the hosiery claimed to be 'beautifully gentle and kind to skin'. Their fibres - "Esprit de Fleurs"- are widely used in such products as clothing and bedding and the microcapsule can be applied to any fibre and woven, knitted or processed into fabrics. For example a cloth or hankie holds 100 million microcapsules. Similar technology is used for microcapsulated skin care, moisturising bras and hybrid materials, such as antimicrobial products called 'Bactekiller' and 'Livefresh'. As with most encapsulated fabrics, the life-span is limited and the '*scent'* lasts from 5-8 washes.

[1] Engineered fragrances for plastics by International Flavours & Fragrances Inc

Asahi Chemicals regenerate cellulose fibres with odour, claiming good resistance when washed (ref. 26). Their fibres comprise microencapsulated Odorants and include viscose, rayon and cuprammonium cellulose. **Matsui Chemicals** fix large amounts of perfume (ref. 27), containing microcapsules, to a textile which emits an appropriate odour constantly and over a lengthy period of time. **Pigeonwill Corporation** introduced *Hib Clean*, (ref. 28) the antibacterial maternity underwear with an impregnated microencapsulated fabric deodorant. These are perfumed with a cypress like scent and although they gradually *loose* their fragrance they can, however, maintain their antimicrobial effect after 60 laundry cycles.

4.4 Environmental Fragrance Delivery

The Sell In Smell

There is absolute truth in the theory of *SELLING IN SMELLING,* or reaching the wallet through the sense of *smell.* Interior designers use colour, music and lighting to convey 'the right mood' in stores, hotels and restaurants. Up until recently *Smell,* one of our most powerful senses, was ignored, although odours are being injected everywhere.

Perfuming the environment is - according to Simon Dwyer [1] -

"Simply an extension of interior design. Just as our eyes are stimulated by colours, our noses will be stimulated by certain fragrances. It is simple musak for the nose"

Nose Control

However, since our sense of smell is so idiosyncratic it would be impossible, by attempting to change people's moods and squirting *scent control,.* to find one single fragrance with the same effect on everyone. If a scent is to be feasible **and** have the desired effect *it must be used at the right time and in short bursts.* 24 hour exposure to one fragrance would not result in around-the-clock activity because, after a while, noses get bored and simply *turn off.*

[1] Atmospherics Ltd, London

Paying Through The Nose

Successful examples of fragrancing the environment include : -

- freshly baked bread smells (especially when there is no bakery on the premises).
- roasted coffee, spices, fruit, Christmas mulled wine.
- pizza and home-cooking smells (impregnated in new homes by Estate Agents).
- leather smells for new car launches, new product promotions for fresh smelling cars.
- appropriate seductive 'smells' for night-clubs, casinos and pubs, perfumed cigarettes.
- popcorn and ice cream “selling smells” in cinemas.
- airports combat the unmistakable odour of long-haul travellers.
- hospices use specific scents such as lavender to relax patients.
- coconut smells in travel agencies to induce the desire for a tropical holiday.
- scent of ' floral potpourri' in US Victoria Secrets successful lingerie stores.
- floral fragrances in jewellery stores - they linger longer.

Mood Fragrancing

Environmental fragrancing also applies for *mood* fragrancing, ie: - *pine needles, sandal wood, leather and flowers.* Museums (ref 29) consequently can be more realistic with historical *smelling* impregnated pieces. Odour absorbers and odour neutralisers are designed to replace bad smells with disinfectants.

Air Fragrance Systems

Traditional air freshening systems are usually ineffective as they rely on inferior technology. Aerosols use hydrocarbon propellants and produce a 'wet' spray which drops out of the air and thus requires frequent applications. Other methods use heating fragrances in hot oil and dissolving chemicals in water and have no consistency, controllability or adequate coverage.

BOC Gases

AROMAGAS by BOC (ref. 30) offers aromas for environmental fragrancing. Fragrance is dissolved in carbon dioxide, which acts as a natural solvent and carrier gas and offers ideal dispersion characteristics – the aroma lingers in the air and is unaffected by heat or solvents. In the future BOC Gases are planning to move into the growing area of the virtual reality business

so that smells can be introduced to make computer games seem more realistic, similar to the ‘multi-sensorial’ storyline in Aldous Huxley's *Brave New World.*

Smell Motivation

The Japanese use aromas introduced via air condition systems to improve staff motivation and raise productivity. Hotels install cash machines, releasing floral and citrus 'natural plant extracts' into the lobby’s atmosphere, to reduce stress in guests. US consumer groups have criticised the growing use of fragrance by retailers, accusing them of subliminal advertising. The pleasant aromas can be compared with background music, fancy lights or plush carpets.

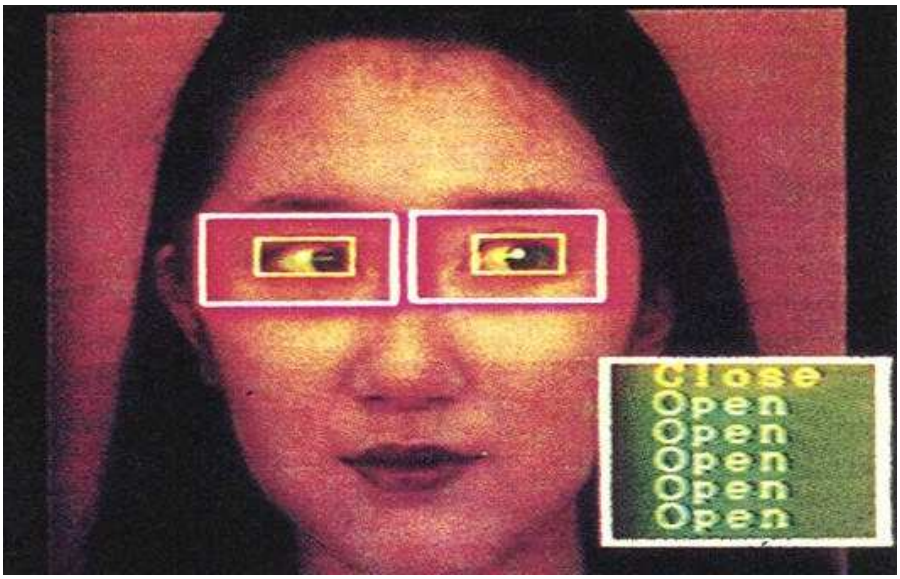
Virtual Scent Reality

Audio-visual Sense Technology is widely available and will be extended to smell using a solid state electronic device which has the ability to give rapid cycling of odours. *'Odorama'* [1] has already occurred at various screenings for films, emphasising scent and vision. Unfortunately, smells tend to follow one another in the air causing a big odour fog and the necessity to install enormous air vents. Radical new developments could lead to *virtual scent reality* which would allow smells not only to be released on demand, but retrieved in seconds.

Smell Beats Sleep

10 % of all road accidents have 'sleep related' causes and 1 in 7 motorway accidents are due to tiredness. (ref. 31) The Japanese Government are enticing manufacturers to halt growing trends of comatosed drivers (however gimmicky) and hope to have *smart cars* available in the year 2000. **Nissan** Scientists have designed a mint flavoured air-freshner which keep drivers most alert in their new car *Cedric*. Having ascertained a link between the frequency of blinking and alertness, a computerised camera is mounted on the facia to monitor not-so-rapid eye movement. Should the driver's blinking pattern fall below a predetermined level the car initiates two *interactive* 'physical stimuli' - a loud buzzing sound followed by automatic blasts of mint squirted into the driver's nostrils (fig. 14). **Toyota** cars are not necessarily injecting smells at drivers but have implanted sensors in the steering wheel. These are linked to the driver's wrist bracelet, measuring pulse rate upon the wheel. Once this begins to fall the car emits loud noises. If this fails, the car triggers the electronic throttle and brakes to a standstill.

[1] Smelly Television



A Nose for Nostalgia

"Is sensory marketing a thing of the future?"

According to Psychiatrist and Neurologist Dr Alan Hirsch,[1] who specialises in treating eating and sense disorders, this is very much the direction of the future. (ref. 32)

> *"Anatomically, the nose directly connects with the olfactory lobe in the limbic system - the area of the brain considered the seat of emotions. Therefore the most powerful impact upon the emotions is through the sense of smell. In a universal phenomenon called olfactory-evoked recall, an odour can bring back a memory from the past and the nostalgic urge to recreate the past within the present",* says Hirsch *"is in many ways, a driving force for behaviour . . . . . .*
>
> **The most direct route to the brain is through SMELL***"*

Work Scent

[1] Smell and Taste Treatment and Research Foundation in Chicago

The emotional power of smell has been chronicled throughout the ages. But applications in retailing have only been around for a while, in the wake of research showing that consumers are most likely to buy (sometimes at a higher price) when in a scented room. By 2010, Dr Hirsch envisages us living in a world in which a 'scent alarm clock' will wake us up, with a 'work scent' driving us and odours helping us restrain our appetite.

Turn On Scent

Dr Hirsch measured a substantial increase in penile blood flow among men exposed to the smell of lavender and cinnamon. Jean Paul Gaultier's new fragrance, *Le Male,* contains both.

Smell Tales

Dr Hirsch also believes that bad odours can promote aggression. Whilst surrounded by pollution and unpleasant smell drivers tend to act more aggressively, causing accidents. When selling a flat it is believed that by placing *sliced green apples or cucumbers* before a prospective buyer's visit the odour tends to make people think that the room is larger. According to various tests, the smell of barbecued meat gives the perception that the room is even smaller.

4.5 Fabric Conditioners and Odour Chemistry

Magical Molecules

The research undertaken at the RCA has not included any *odour chemistry,* as originally anticipated with the Biochemistry Supervisor, Dr George Dodd. The design and selection of *key impact Odorants,* however, is essentially very important for this project and future experimentation. This subject alone is a separate area of research in itself. Eventually it will be necessary to specifically design *new magical molecules* for fabrics, and, by analogy, with biological receptors with distinctive adsorption [1] and de-adsorption kinetics.

Cashmaran

When that stage arrives suitable available Odorants will be investigated. A chemist from International Flavours & Fragrances in the USA, Bill Taylor,[2] had a huge success story with the perfumed molecular engineering of 'cashmaran'. This acts as a functional odorant for washing garments in the modern-cycle which binds to fabric, dries and gently releases a "musky/woody" smell. All major Fragrance Houses spend large budgets on Research & Development in mood modification and life expectancy for house-hold products - primarily washing powders and fabric conditioners. The 'fresh' and 'clean' market for maintaining scented washing products is unprofitable because at least 80% of fragranced fabric conditioner is wasted down the plughole.

[1] To take up a vapour on its surface
[2] IFF Research & development Director in the 1970's

4.6 Insectal Pheromones

Delicately Back To Nature

Insects have the most acute sense of smell in all nature. For example, the alarm pheromone of honey bees, the sexy scents of courting moths and the pheromones used by ants to mark their trail home. Insectal *olfaction delivery systems* use 'signal scented' chemicals, with the architectural device of *active - pumping - spraying* tubular structures (ref. 33). Their robot-like response to odours and the delivery system (in certain insects) - which is called *the pencil* - could be necessary for the delicate mechanisms behind the design work for this research project. The hairs in the pencils are lattice like structures and provide *Interactive Olfactory Surfaces; in conclusion,* nature may have solved the problem.

A World Of Scent

Most moths fly at night and the males and females use scents (pheromones) to find each other. The female is the 'calling' sex, with several hundred species living in the same area, so each one will give out its own unique scent. Male moths are extremely sensitive to the scent of females and a silk moth can detect a calling female from 4.4km away. Many male moths have antennae with feathery out-growths which increase the surface area of the sense organs, making them more sensitive to the pheromones. In species such as the Oriental fruit moth, when the male has been attracted to a female by her special scent he courts her by displaying a brush of hairs on his body called a *'hair brush'* or *'pencil'*, which also gives off scent. Salt moths display their coremata.[1] This induces her to touch his abdomen and when she does, they will mate.

The Working Pencil

Once the male moth locates a calling female, he alights 1-2 cm from her and rhythmically extends and extracts *brushes* from the rear of his abdomen. (Figure 15). He will also generate puffs of wind by vibrating his wings, which pass over the hair pencils, helping the pheromones to evaporate and disperse. Hairs on the brush are fanned by a muscle at their base and scent is stored on the brushes within the pockets until mating occurs. The pheromones of the oriental fruit moths have a pleasant, herbal odour to the human nose and provides the major stimulant to the female moth. She is attracted, stopping only when in contact with his hair brushes, which in turn stimulates him to attempt copulation.

[1] Inflatable tubelike organs which secrete pheremones

Honeybees

The organisation of a honeybee colony is fascinating. There is a single queen and up to 80,000 workers. She lays 1,500 eggs a day and has a *fatal attraction,* exerting a chemical control over her workers, secreting an olfactive *signal scent,* called queen substance, from glands in her head which she spreads over all the workers, preventing them from further egg production .

Bombardier Beetles

'Chemical warfare' (ref. 34) is used as a form of protection for the *bombardier beetle,* as they produce two chemicals in separate glands at the tip of the abdomen. When disturbed they *squirt* a jet of both chemicals at their enemies as self defence and when the chemicals mix in the air there is a short explosion so that predators are covered with a vile, hot and skin-blistering mixture.

4.7 Conclusion

Ink Jet

Insectal Pheromonal is a similar process to the highly mechanical technology of an *'ink jet printer',* a promising area which unfortunately has not been fully explored during the research process. This method requires an inserted heating device to be triggered by the sensor, in order to activate the 'squirting' technique. Returning to nature's mechanical devices, the squid and octopus have a tendency to 'squirt' ink at their predators (similar to the skunk), which in a sense is a deterrent atomiser (ref. 35). Other more day-to-day mechanical delivery systems include heating devices and ceramic gels, as well as the ever-growing area of drug delivery systems and tubes, which will be discussed in Chapter 8 on the Electronic 'Pulse'.

Odour Pollution

It is essential to review the ethical issues regarding Environmental fragrancing and odour pollution, however minor this may be. Recent research proves that there is an evident increase of asthma in children, which could easily be connected to the increase of odour injected pathways. Naturally, this is an important issue to consider when designing 'nano' [1] delivery systems for fabric structures, emphasising that scent release must be minimalised and controlled accordingly.

[1] Ten to the minus ninth power, or one billionth of a measurement

Triggering

Having differentiated between the appropriate mechanism of *delivering* a fragrance (as described in the previous examples), which is 'smart' in its way of thinking, technologically advanced and far removed from the area of *micro-encapsulation* - it is necessary to choose the mechanics for delivery and then examine both *'triggering'* and *'the electronic pulse'*. This will be distinguished in the following chapter by asking - how, why, when and for what particular reason a fragrance would be 'triggered' and electronically pulsed as a release mechanism from a new smart fabric. Using the recorded research collated, it is important to concentrate on : -

(i) The lifespan, how long will the fragrance linger once released?

(ii) Which technology will be able to easily control the new interactive delivery system ?

Chapter 5

5 The Triggers - *'The Inner-telligent Dermis'*

5.1 Introduction

The "Inner-Telligent Dermis"

This chapter concentrates on how a fragrance can be '**triggered'** (*or actively prompted*) in order to freely *release* itself out through the fabric surface. This can be easily deciphered as the inner 'skeletal intelligence', or *brain-power,* within the fabric dermis area which controls all information and commands. *Sensors* are the most important element in any temperature control or monitoring application, and to cope with extremities of environmental conditions the sensors' physical shape and design will have a big influence over the whole performance of the system. This chapter will also discuss the 'electronic-nose' and applications in the wide-ranging marketable products, including the interestingly futuristic field of transdermal sensing, incorporating *'biosensors'* in smart fabrics.

5.2 What ***Triggers*** The Release

Switching

The triggering action is the direct order or contact, *'switching on'* and *'switching off'* the fragrance delivery, and is incorporated within the smart fabrics. It is similar to the human sensory organs, which are electrical mechanisms, and sensations such as cold, pain and pleasure, which are electrical phenomena.

The Smart Interface

This 'switch' can be triggered by the *interface*.

The Smart Interface is a 'situation' where *interaction* occurs between two systems.

For example this could be the human body and a 'condition or feeling' triggered by : -

Body Temperature - hot, cold, fever, shivering, hypothermia, 'goose pimples'

Body Odour Signature human pheromones, perfume, illness, perspiration, sweat

Fear - voice recognition, anxiety, stress, heart rate, skin response

Sexual Chemistry - attraction, love, desire, arousement, human pheromones

Insecurity & Security - familiarity, confidence.

Interaction could therefore occur in the following situations : -

i) An individual's interaction with his/her own personal body and worn garment(s).

ii) The interaction of two persons and all clothing involved by either Partner.

The surface forms a common boundary between two individual regions. When an interface situation occurs it sets off the *triggers* which could be involved with : - *smell*[1], *energy levels, anxiety, stress, mental defects*,[2] *blood pressure* [3] *or sexual arousal* [4] .

The triggers are the 'smart' interface of the fabric and could eventually be *pre-programmed* with your own personal body odour or partner's body odour for comfort. Examples include : -

Familiar odours, household odours, hospitals odours, certain illness smells, dangerous odours, gases, poisons, vegetation, drugs, food, perfumery,

5.3 An Osmical System

The majority of the research has been directed towards finding ways in which fragrance can be triggered using developing biosensing techniques, influenced by the body. Utilising a variety of biosensors clothes will evidently interact along the following ideas :-

[1] Body Odour, sweat, perspiration and Pheromonal levels measured
[2] Mania, depression, low self esteem, hyper-tension
[3] High or low blood pressure
[4] Musky aromatic molecules released through the skin, increased heart beat, breathing

A person on their own - interacting with their own clothing.

By a person's body odour signature (pheromones, personal perspiration), body temperature - especially under the arms, back, groin, neck fever, [1] and from the effects of anxiety, over-excitement and sexual arousal.

The interaction of two persons.

By the energy levels generated between two people or the "Emotional Presence" including love, attraction, sexual chemistry, confidence, security/insecurity, voice recognition, familiarity, recognition of pheromones. *The Smell of Fear* for self defence or an instinctive *danger warning*

5.4 Nature's New System

The Electronic-Nose

As a researcher in olfaction, including the positive aspects of how the forthcoming century will benefit tremendously from the sense of smell, the research will endeavour to explain the principal facts of artificial noses - or commonly named - ***'the electronic nose'.*** At present, the 'nose' technology is complex and chunky, literally the size of a fridge, but assuming that in the future this technology will shrink to nanometres an entire 'electronic nose' will be fabricated as a miniaturised 'chip' using nanotechnology. This would be the perfect replica of a human nose (but certainly no better than a human nose), eventually taking the form of a *nose-on-a-chip* 'trigger', sensing and detecting odours and subsequently responding to its particular trigger signal. The nano-chip will fit unobtrusively into a garment, but however fascinating and beautiful the concept is regarding *nose-triggering* in smart fashion, it is at present far from being achieved and the costs will be phenomenal.[2]

Imitating The Architecture Of *Olfactory Systems*

The human senses of *sight, hearing, taste, touch and smell* allow us to analyse our environment, to sense and react to changes that occur within us. Measurement of light, sound and temperature has been possible for some time. Rapid and accurate electronic analysis of smell and taste - being closely related - has remained elusive until now. While computers have been given the ability to see, hear and touch, they are as yet unable to emulate the olfactory organ - *they cannot smell.*

[1] High temperatures cause immense sweating or shivering
[2] In 1997 an *electronic nose* costs in the region of £20,000

This may well change soon with PC's recognising personal body odour. Instead of plugging in tedious passwords - we will instead experience an interactive 'Pheromonal log in'.

Nose On A Chip

An average human nose recognises 2000 aromas whereas an expert 'nose' [1] can be trained to differentiate 10,000 aromas. The **e-NOSE** 1 mimics the three phases of the human olfactory system using a computer as 'the brain'. ie: - detection, signalling processing and recognition/interpretation. The sensor has 32 polymer types which detect a spectrum of compounds similar to that of the 30 receptor families in the human nose. These polymers are the sensory part of an *electronic nose* and a 10 micron thick polymer could one day totally challenge the human nose. Initial data processing - carried out in the olfactory bulb - is performed in the electronic nose processor which contains aroma 'maps' and aroma 'finger prints'

Nose On Legs

Dr George Dodd has been working in nose technology since the 1960's. He claims that the knowledge of a sniffer dog being able to identify individuals through smell kept him going throughout those years. A dog's keen sense of smell has often proved handy to humans, helping them to track down drugs, explosives and dead bodies - and now, after 30 years - technology is catching up with the dog.

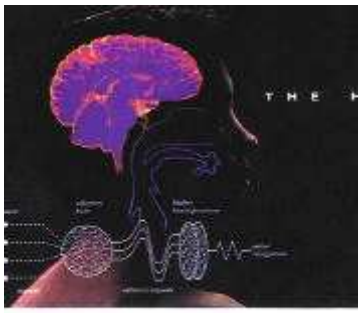
Warwick University

The world's first commercial electronic nose was developed at Warwick University (with Bass & Neotronics) (ref.. 36), which Dodd founded in 1971[2].) The technology mimics the way the human nose detects molecules. Neotronics Scientific **e-NOSE** [3] - *the second generation electronic nose system* - is far more powerful and sensitive than the first, using state-of-the-art technology for aroma analysis which aims to invent novel, non-invasive clinical diagnostic methods based on slight changes in body odour.

[1] A term used for a professional perfumer
[2] The Warwick Olfactory research group
[3] **N**eotronics **O**lfactory **S**ensing **E**quipment

Nose Brains

The technology is applied within a wide range of processes in different industries. Using unique sensor manufacturing processes they are able to produce sensors which are the same every time. When a sensor dies it can be replaced with an identical one giving the same result and can differentiate between samples and identify impurities, even at the lowest levels, offering a new analytical capability to quality control and quality assurance laboratories.



The '*Electronic*' Nose

The AromaScanner is an effective quality control tool for the development and manufacture of flavours & perfumes

Research in this technology is underway in Scotland at the Nanotechnology Centre (ref 37). AromaScan PLC (ref 38 and fig. 16) have also pioneered the concept of global aroma management, monitoring and classifying odours. Its performance emulates that of a human nose, with high levels of discrimination, sensitivity and reproducibility.

Breath Analysis

At a Scottish Psychiatric Research Group (ref 39) Dr Dodd and other scientists are sniffing out diseases and have recently been offered further funding to pursue their ambitions. Researchers have linked odours on peoples' breath or sweat glands with disorders, from ulcers to lung cancer, manic depression and schizophrenia, and have been researching breath analysis to detect ovulation, allowing monitoring of women's menstrual cycles. This will potentially provide huge

benefits for in-vitro fertilisation and birth control. Dodd strongly believes hospitals may one day have booths like telephone boxes, filled with *sniffing sensors,* to 'sniff' out diseases.

Other examples of the diagnostic potential of breath analysis include : -

neonatal screening - mass spectrometry - drugs - ethanol - acetone anaesthetics - trichloroethylene - respiratory function - toxicology diet adherence - metabolic disease - blood gases - physiological and pathological correlates - occupational hazards.

Pheromonal Future

Dr Dodd works with human pheromones, promising that one day future projects will single out the compatible odour of a potential mate in any social situation, as a move towards protecting mood through smell. Experiments in the States are already testing our susceptibility to certain scents. For example, 1 of 10 identical chairs was sprayed with a chemically formulated *aggressive* odour. While men ignored it (seeing it as *marked* territory) women chose to happily sit on it, giving them the supposed sense of sanctuary.

Japanese Technology

Tokyo based Nippon Telegraph and Telephone (NTT) (ref 40) claim to have developed an electronic smell sensor that can detect gas concentrations of a few parts per billion - ten times the sensitivity of conventional sensors. The sensor consists of an array of eight quarts crystals, each coated with a different organic gas absorption film. The resonant frequency of each crystal is affected by gas absorption and is monitored over time. The array is sensitive to a variety of smells and a PC performs pattern recognition to differentiate between burning smells. The sensing technique can be extended to detect virtually any gas or odour.

The Food Industry - *Is it "off?"*

Artificial nose technology is currently used to smell the maturity and freshness of cheese, bacon, coffee, herbs, fish and milk. The alcohol industry sniff out quality control in beverages with the added bonus of being able to 'sniff' out everything, including the best wine and fruit. *Is it really 'off'? Is it contaminated?* Currently, shops sell food stamped with a 'sell by date' - the 'paper' equivalent to the 'e-nose'. In the future we can look forward to this essential stamp being 100%

reliable on *all* foods and drinks, due to future technology sniffing bacteria, salmonella and listeria a mile away

Environmental & Healthcare Sectors using the *electronic nose* technology include : -

Water industry and the treatment of sewage.

Plastic packaging and odours which are potentially harmful.

Cosmetics which are unscented come in fragrance-free formulas and have their odours masked with a chemical which is detected by the *electronic-nose* technology.

Perfumery, toiletries, pharmaceuticals.

Hospitals whereby electronic nose devices detect/distinguish infections at an early stage, in order for treatment to commence.

Poisons , drugs and gases.

Anti-perspirant companies by relieving employers from the old method of sniffing armpits.

Diseases ; - cancer, kidney and liver diseases, diabetes, asthma , multiple sclerosis, arthritis.

Cows On Heat

This novel technology will revolutionise the detection and identification of volatile chemicals in many areas of Research &Development, manufacturing and monitoring of chemical and biochemical systems. An *electronic nose* can be used to find out what makes a bull 'tick', by using a device that detects the chemicals which make a cow more alluring to its mate. This technology is currently developing over the next 3 years with backing from the Ministry of Agriculture, Fisheries and Food and is also being used to look at pollution levels in farm yards and 'oestrus'[1].

[1] Cows on heat

Robot Mouth

Researchers at Cornell University, Upstate New York, have developed a proto-type artificial 'mouth', a blender-like device that mashes food and detects the chemicals present. Allied to the British electronic-noses, the technology could create a robotic wine-taster.

Smell Bank

The Association for Payment Clearing Services (APACS), which deals with credit card fraud, is currently studying the biometrics and ways of identifying individuals other than by the PIN number. (ref. 41) Pressing a finger over 'smell sensors' at the bank could mean the end of plastic cards, making it practically impossible to access your account, or more appealingly - for anyone else to get your cash. The only draw back is that a finger print will never change, where as a smell obviously will.

Clocking Smells

Companies will soon use 'smell security systems' for clocking in - like the card system but set to recognise ones own unique scent with a pheromonal barrier.

Doctor Detector

Fibre-optic cables *could* possibly one day diagnose a patient 'over-the-phone' in a doctors surgery. This may appear like total *science-fiction,* but once the *electronic nose health detector* is operating along a phone line consultants will view patients on-screen as opposed to in person, resulting in no doctors visits.

5.5 Examples Of Triggers

Control Your Bark

A controversial American device, recently available in the UK (ref 42), can teach a dog to make less noise by giving it a mild electric shock. The manufacturer claims that the device does not harm the dog, although it has not gone down well in animal circles. *Bark Controller* fits on the pet's collar and has a sensor that detects larynx vibrations when the dog barks. It then gives out a warning *bleep* and, if the barking continues, issues a brief six-volt shock. Marea Brown from the British distributor, Petsafe, claims to have tried it herself and that the electricity 'jolt' does not

hurt the dog. However, the *Bark Controller* has more positive technology purposes as a communicator, by remotely giving a dog a shock if he strays.

Hot Badge

The Electronics company *Philips* (ref 43) have invented a gift to avoid corny chat-up lines. The magic badge with a personal computer 'lights up', for tongue-tied lovers. Instead of eyes lighting up across a crowded room - a *hot badge* on a jacket sends out signals. Each badge is packed full of detailed personal information about the wearer which is down loaded onto a chip. If the details match, when another *hot badge* is near, both badges start flashing.

Finger On The Pulse

Nonin (USA) are leaders in Non-invasive Medical Monitors and have created the *Onyx*, a durable and accurate self-contained finger pulse oximeter for finger thicknesses between 0.3 to 1" (fig. 17)

Self-contained *Finger Pulse* Oximeter

Non-invasive Medical Monitors

5.6 Biomedical Sensors

Chemical Sensors For *in vivo* [1]Monitoring

Clinicians or patients need a way to continuously monitor the concentration of several key metabolites inside the body, eg : for glucose control in diabetes or multi-analyte monitoring during critical care. Sensors can operate inside the body for hours, days or months, giving continuous information on analyte concentration.

Sweat & Blood

During December 1996 the research had the opportunity to visit the University of Cambridge and meet Dr Christopher R. Lowe, Director of the Institute of Biotechnology. Although Dr Lowe heavily stressed the *vast* expense of integrating biosensors in clothing related to this research project, he was willing to discuss the possibilities and view miniaturised chip systems. At present, he is currently funded, and developing biosensors, for 'smart' biomedical cards and exploring the detection of heroin and steroids in urine and blood. How can we easily characterise a sensor for 'sweat'? Whatever is in the blood is also in the sweat, in differing concentrations and with relative time delays.

Biosensors

Biosensors [2] promise to provide an analytical and powerful alternative to conventional approaches by being able to discriminate the target analyte from a host of inert and potentially interfering species. They are analytical devices that respond selectively to analytes in appropriate samples and convert their concentrations into an electrical signal via a combination of a biological recognition system and an electrochemical, optical or other transducer. Biosensors are used in the home to monitor blood glucose in diabetics (ref 44) and are well suited to satisfy the demands of 'alternative-site' clinical biochemistry. For example, there is a growing demand among general practitioners working in local surgeries for low-cost analysers to assist in real-time diagnosis during consultation.

[1] In the living body or in this case, the body
[2] Analytical devices responding and converting concentrations into an electrical signal via a biological recognition system and an electrochemical, optical or other transducer

Intensive-Care Biosensors

Similarly, in intensive care units patient-side testing with portable devices capable of continuous monitoring of key analytes is highly desirable. Single-use diagnostic devices allow quantitative or semi-quantitative estimation of analytes in the home or work-place and are becoming increasingly popular. Biosensors have their greatest impact where there is and advantage in obtaining a rapid analysis, ie: - within the operating theatre for checking cancer markers in tissue or patients suffering from a drug overdose.

Transdermal Sensing

There is increasing interest in *transdermal sensing* for biomedical measurements, which is now routinely employed using iontopheretic devices [1] to aid the diffusion of substances through skin. Ionphereric systems are documented for the research process in Chapters 8 & 9 with respect to Medical Textiles and the Electronic 'Pulse'. Sensors are integrated with this technology to provide non-invasive diagnostic tools. Dr Dermot Diamond, Research Director of the Biomedical & Environmental Sensor Technology Centre, Dublin City University (ref 45), has been developing thin and thick film fabrication technologies, virtual instruments, electrochemical and optical sensors; and solid-state electrodes suitable for skin contact measurements, with resulting sensors showing good stability and economical devices.

Trends in Sensor Technology

The potential for information generation has always been greater with optical sensors, which are extremely complex, large and expensive but electrochemical sensors can be used in applications more quickly. The market driving force in biomedical instrumentation will lead to a rapid expansion in the use of sensors, either miniaturised implantable devices which will be discussed in Chapter 8 in The Electronic 'Pulse', or as integrated sensors for new 'smart' medical devices, or as integrated components for intensive care monitoring. Biomedical Monitoring is ideally non-or-minimally invasive, or else can be introduced via catheters with built-in sensor capability. Research and development in sensor technology is developing rapidly in terms of range of target species, fabrication technologies and transduction.

[1] Microprocessor control unit with internal battery applied to the body containing electrodes and used to deliver drugs

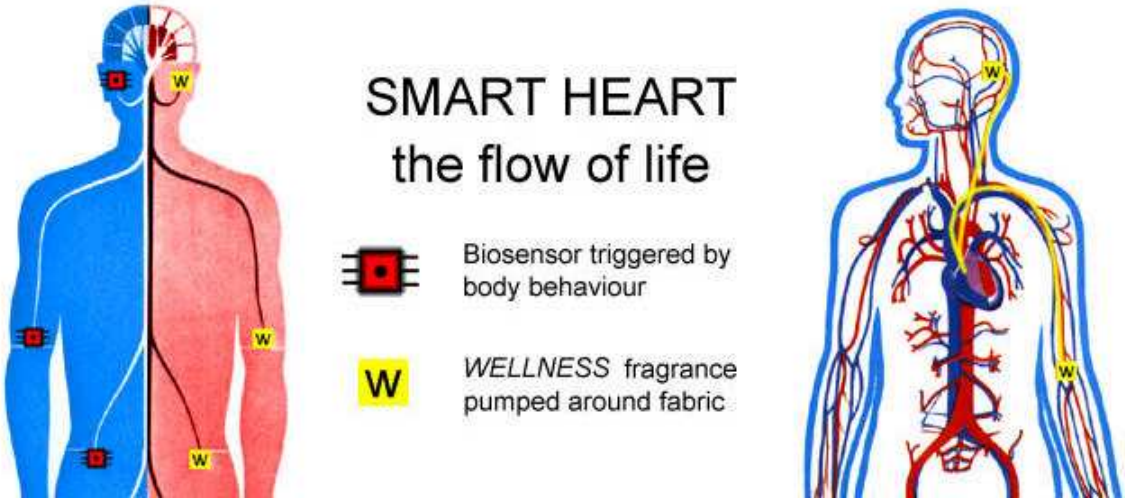
5.7 Conclusion

Question For Fragrance Release & Monitoring

How can it be controlled? How can it be protected? How can it be washed, dry cleaned? How can it be recharged, replaced or refilled?

Science Fashion

Although this chapter deals with recorded research from all scientific scopes, it also strongly relates to biosensors and triggers necessary for this research (fig. 18). Over the next few years, these particular technological areas are going to expand considerably, miniaturise even further to the extent where they are flexible manipulative structures. Nevertheless, it is fair to say that the artificial fibre-nose technology is at least 10 years away if we are to expect that a smart active fabric will mimic a nose and scent glands. Once this technology is available and built, bonded or implanted into fabric a hospital doctors white coat could inevitably *sniff the diagnosis.* Hence, the vision of science-fiction 'triggering fabrics' will inevitably lead to a science-fashion era.



Fashion Sandwich

It is now reasonable to accept that the triggering smart interface - or the ***"inner-telligent dermis***" is sandwiched between a coating layer area. Chapter 6 compares this protective surface area (or the "***outer-shell dermis"*** of a Wellness fabric) to the human skin and is described as the *Dynamic Surfaces*. It is similar to the human sensory organs which are electrical mechanisms, where sensations such as cold, pain and pleasure are electrical phenomena. 'Wellness' logic *could*

possibly one day be able to detect emotions like stress, measuring electrical skin surface tension and temperature and correct correlation**.** More complex - are illnesses or 'matey' states in Wellness.

Chapter 6

6 Dynamic Surfaces - *'Outer-Shell Dermis'*

6. 1 Introduction

Live & *Active*

Dynamic Surfaces combine fabric with the forefront of technology to create entirely new ways of communication and self diagnosis towards 'Wellness'. In this chapter, the qualities of a dynamic surface will be explained as if it could be a *living* smart fabric - which is active, reactive, kinetically moving, visually stimulating and imitative of the living tissue of human skin. It is necessary to research the true purpose of textiles and compare human skin properties of the 'dermis' and 'epidermis' - to dynamic surfaces. Other references in this chapter include research in Space technology, fabrics used by the Ministry Of Defence and heated performance fabrics.

Nanometre [1] Tiny Tubes

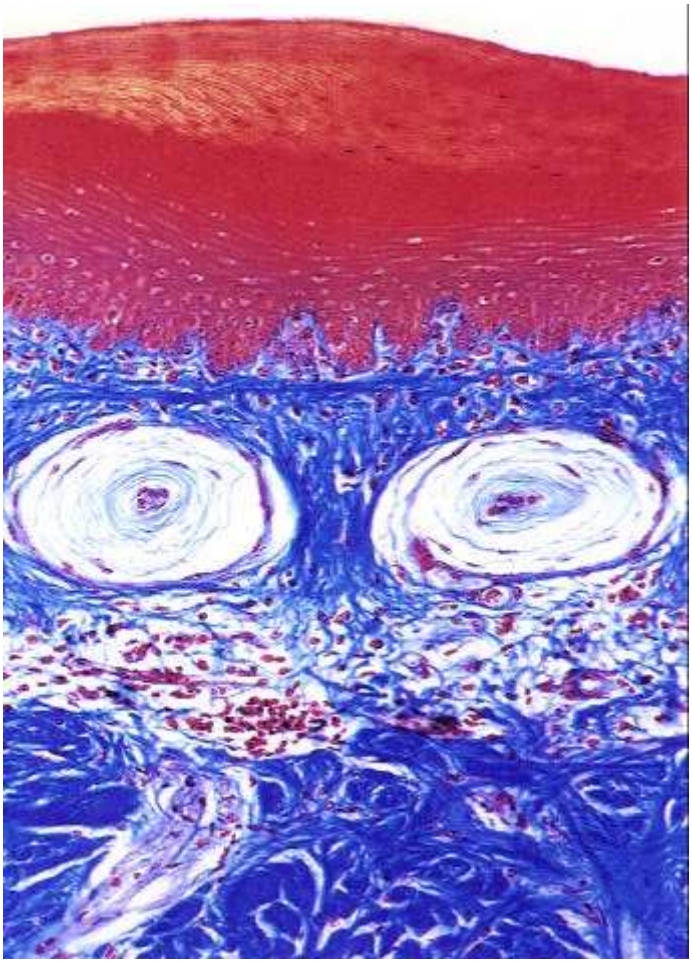
The objective is to build an integrated system in order to find ways of *ducting* smell in fabrics in a manageable **on/off** way, using electronically *pulsed* perfume. Micro-bore (and eventually *nano-bore)* tubes will be used as a *capillary flow system* connected to a reservoir in a micro drug delivery system. *Re-cabling* therapeutic clothing requires measuring in *nanometers.* Eventually, the research will require 'nano fibres' with hollow centres, identical to the narrow tubes found in leaves and plants, enabling water to travel vertically.

6.2 Human Skin

***Living* Tissue**

Human skin is a tough, waterproof, continuous *living* tissue which, surprisingly, is the largest organ in the body (fig. 19).

[1] One billionth of a metre



It is not merely a thin boundary protecting the inner person from the outer world, but a multi-layered organ *(the dermis*) with its' own nervous system and blood supply. New cells are constantly pushed to the surface, changing function and shape on its long journey. Cells cluster together to form tissues which come together to form organs. Even when cells die or wash away they are acting as a protective germ-free layer (*the epidermis).* Not only is skin an excretory organ and defence barrier, holding the internal organs together, it is a prime source of research relevant to *dynamic surfaces*, for a number of reasons : -

(i) *Because skin changes all the time, grows, sheds, changes colour and temperature.*

(ii) *Beneath the surface of the skin, complicated areas occur such as muscles, hair shafts,sebaceous and sweat glands, nerve endings respond to pressure & stimuli.*

(iii) *A third of the bodies blood is pumped from the heart to the skin.*

(iv) *It is the major point with the surrounding world - whereby it receives sensory messages from the external environment which are passed to the brain.*

The Epidermis

The dermis and epidermis are knitted together by 'plugs' and millions of microscopic 'cones' called *papillae.* Skin on human finger tips form a pattern of ridges - a *smart* surface which is totally unique to the individual and have been used for identification purposes long before written signatures. The epidermis consists of four layers made up of horny cells and no nerves, growing up and outwards to the surface. The lowermost layer is near blood vessels and controls 'colour', containing pigment cells. This will subsequently interact with sunlight - depending on caucasian, albino or Negro skin colour.

The Dermis

Below the epidermis is a strong, thicker connective tissue called *the dermis.* Specialised nerve ending *membrane-mechanisms,* used for registering 'touch' sensations (pain, sexual pleasure, heat, pressure) are embedded in the dermis, directly beneath the arches of the papillae. Skin is perforated with approximately two million sweat pores, distributed unevenly around the body e.g : palms of the hands, forehead, nose, armpits, groin and soles of the feet. Sweat glands lie deep in the dermis and spiral through layers of horny epidermis cells - out of a tiny pore. Not only do these glands in the dermis predominantly produce salty fluids, but more interestingly, *pheromones* from the modified scent sweat glands, aiding sexual attraction. In humans these are located in our armpits, navel, genital and anal areas.

Connective Tissue

Connective tissue is the supporting structure to every organ of the body with three types of fibres :

collagen fibres which are white, flexible but non elastic, occurring in bundles, and contain a simple protein, woven into microscopic strand patterns.

elastic fibres which are yellow, highly elastic and occur singly.

reticular fibres which are the very thin and highly branched.

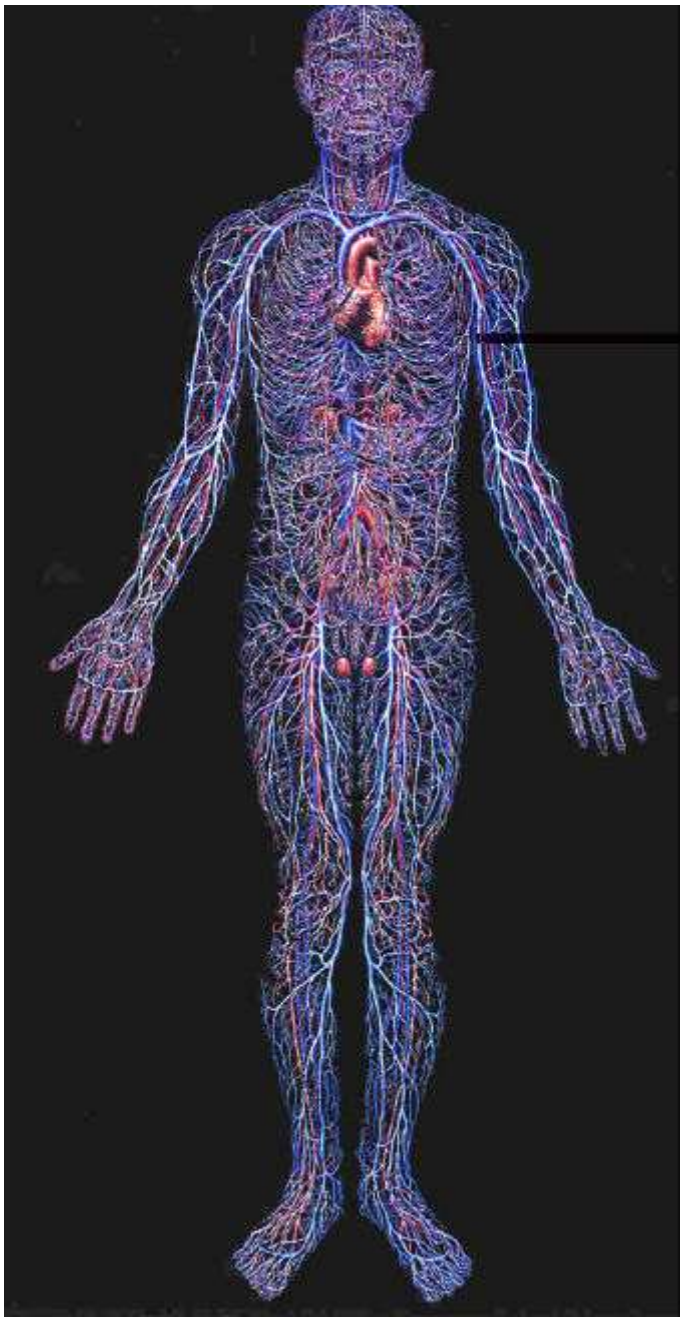
Ageing Fibres

At first the fibres are as loose as those in *cotton* but later they become firmer and denser. Our skin stays flexible and the features of our face retain their characteristic texture because these fibres retain their original tone. In time, the fibres age and their elasticity decreases visibly. The first signs of ageing, therefore, show themselves in the connective tissue fibres.

6.3 Dynamic Surfaces

Second Skin

Comparing the similarities between layers of human skin and smart *living* fabrics, it is foreseeable to distinguish the *dynamic surface* as simply *the surrounding shell, second skin or* ***'outer dermis'.*** This can also be viewed as a *dynamic* fashion fabric, covering and protecting the 'smart interface'. It is beautiful, *multi-sensorial* and aesthetically appealing, unique in the sense that it looks and feels like any other fabric or flexible surface - but containing a skeleton intelligence deep inside. This skeleton within the fabric is a mass of *intelligence* similar to the bodies capillaries and internal nervous network system, illustrated as a dynamic surface in figure 20. Once the initial 'trigger' (*inner-telligence dermis*) occurs, the surface (*outer-shell dermis*) will change accordingly.



Psychological Interaction

Stimulation occurs for ALL senses by interacting with our behaviour, moods and emotions. The 'smartness' of these fabrics also has the capability to read the body's state (physical and mental state) and respond accordingly. In other words, they can literally monitor and alert.

Cross section illustrations of a 'Living Dynamic Surface' (fig.21) and a 'Colour Therapy Fabric' (fig. 22) demonstrate how the intelligence will allow the surface to : -

LIVING "DYNAMIC" FABRIC

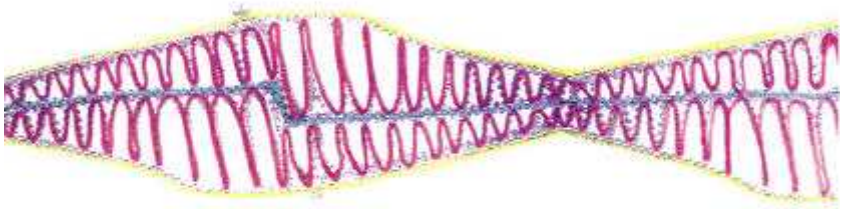


Diagram 1

This shows a cross section of a 'dynamic' fabric semi-fixed flexible wall. Tubing is sandwiched between the outer shells of fabric and a flexible inner diaphragm wall. Fluid (fragrance chemicals) is "pulsed" through the tubing for special aromatherapeutic body 'massaging'. The tubing would be connected to a network operated by sensors, miniature pumps and customised atomiser (which would be disguised in a button, cufflink, piping, zipper or jewellery)

"Pulsing tube" Flexible wall tubing semi-fixed at strategic points

Upper and lower fabric outer shells. This could then be coated with any fashion / couture fabric (sandwich)

Flexible diaphragm

Change Temperature

Alternating *body temperature* scented fabric surfaces which rapidly or slowly warm up or cool down.

Kinetically Move For A Massaging Effect

Aromatherapeutic moving surfaces - *Stimulate, Relax, Deodorise, Motivate, Energise, Soothe or Arouse.*

Change Colour

Change Surface Colour and Odour on demand.

Emit Odours

Scent-releasing fibres deeply implanted within fabric which alternate fragrance preference on signal demand.

Medication

Fabric Surfaces will act as a global sophisticated *Controlled Drug-Delivery System.*

Expand & Detract

Fabric surfaces with an expanding/detracting surface area for protection / weather conditions/ warmth.

Transmit Digital Information Technology

'Alive wire' or 'Living vein' fabrics pulsate optical fibres, transport digital information.

Monitor Body State

Surfaces will control and monitor signals from the body ie: Blood Pressure / Sugar Levels.

Release Sounds

Warning or Reassuring / Calming Sounds / Music released through speakers built into the fibre and conductive fibres in fabric transmitting *sounds*.

6.4 Heated Surfaces

Electro-conductive Textiles

Heating engineers have been restrained by *'metalo-electric technology'*, which is considered unsafe, uncomfortable, incapable of monitoring small degrees of temperature and risky to million dollar race horses. The British company, INFRA-THERM Therapeutic Aids, have developed a new electro-conductive carbonised-fibre fabric called **GORIX.** (ref 46) This is a versatile material with both passive (sensory) and active (heating) electrical states, achieved by the same circuit. Infra-therm therapy systems increase blood flow to injured and painful joints, penetrating deep into soft tissue, muscular injuries and arthritic and rheumatic conditions.

Red-Hot Power To Heal

The safe low voltage of these fabrics uses an impregnated infra-red emitting element, encapsulated in a multi-layered textile-metallic sandwich, encouraging rays to travel towards the effected area. Its linear change in resistivity is a prime characteristic as a response to temperature change. Using simple circuitry, an efficiently accurate combined *temperature control* and *heating system* is corporated, sensing temperature change over large areas. This can supply enough power for it to remain at 34 degrees centigrade. The fabric can be laminated to materials forming a fully encapsulated, permeable or ventilated element or sensor. In contrast to matrixial wire elements **GORIX** will not cause hot spot problems, is ideal for biomedical applications, de-misting road signs and the ultra low electrical resistance allows high wattage with low applied voltage for car seats and diving suits (fig. 23). In the future, this fabric could allow us to throw away the central heating boiler and use Gorix to heat our carpets. Mr Rix, the Director of the company, believes that it would slash heating bills as well as help to circulate the blood back into cold skin.

COLOUR THERAPY FABRIC

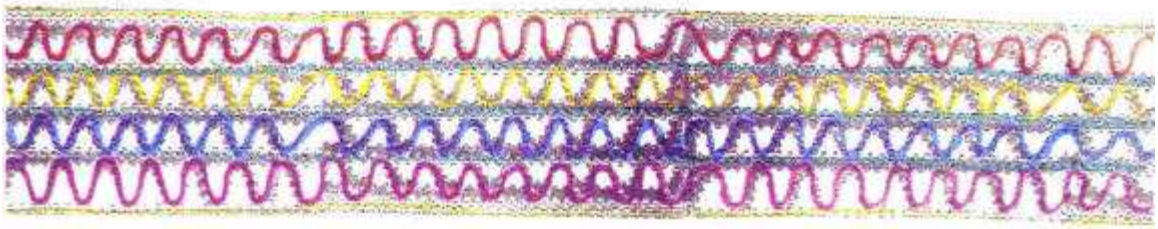


Diagram 2 - Multi layered

This shows a cross section of a " multiple layered" cellular fabric containing semi fixed tubing. These tube ways are separated by 3 flexible wall diaphragms and all sandwiched between the outer shells of fabric. Here multi lumen tubing is used which can carry both different fragrance chemicals and fibre optics for digital information.

- Example of fragrance delivery 1
- Fibre Optics for digital information
- Sound Waves (ultra sound)
- Example of fragrance delivery 2
- Upper and lower fabric outer shells. This could then be coated with any fashion / couture fabric (sandwich)
- Flexible diaphragm

6.5 The Ministry Of Defence

Dressed To Kill

A research programme called "Crusader 21" at the *Defence Clothing and Textiles Agency,* Colchester (DCTA) (ref 47), looks at the effectiveness of UK Combat Forces in vehicles, ships, battlefield and aircraft scenarios after the year 2000. Crudaser 21 requires innovative and revolutionary approaches to smart materials and clothing systems over the next 25 years, linked to a research programme called the "Future Integrated Soldier Technology".

Military Communication

This concentrates on *electro-optical sensors*, sights, communication systems and battlefield information computers which may interfere with 21st century fighting individuals. Crusader 21 believes that it is absolutely necessary to forget the constraints on current clothing and textile technologies which make up the previous "Combat Soldier 95".
Future Combat Research Materials include : -

Reactive Materials

Smart fabrics are used for flame and heat protection to prevent conducted, convected and radiated heat reaching the skin - whereby a thin flexible liner instantaneously develops thermal insulation, preventing discomfort of several passive insulated layers in hot climates.

Thermochromic Dyes

Dyes change colour with heat, turning colourless from original army colours - black, brown and khaki. This colourless fabric exhibits a white base reflecting levels of radiant flash energy, reverting to army colours when cooled to the original temperature.

Buckling Fabrics

The fabrics form double cloths and 3-dimensional cellular structures (including Shaped Memory Materials [1] originally from the military, now popular in modern lingerie) and possess increased thermal insulation whereby the outer layer remains dimensionally stable.

[1] Intelligent material resuming its original shape according to body temperature and imprinted with two shapes

Expanded Waddings

The technique is based on thin non-woven 'scrims' held together by low-melting point adhesives which melt when heated, expanding and causing a higher level of insulation.

Gas Injection

Tubes in clothing are attached to a canister of pressurised CO2 gas. When heated, they rupture and release fire quenching inert gas into the affected area.

Intumescent Treatments

Treatments are incorporated into textiles layers or thin films. When attacked by heat they swell forming an inert insulate char near the outer surface. Research is necessary to activate rapid treatments, laundering procedure and resist abrasions.

Smart Materials For Protection Against The Environment include : -

Shaped Memory Alloys

The alloys change shape reversibly, in pre-ordered ways by coiling/un-coiling, shrinking and expanding. This could be exploited, wherever a temperature change needs to be exposed in textile materials. Thermal insulation properties could be automatically adjusted by stretching, buckling or uncoiling to alter the still air trapped by the fabric layers. 'Smart' materials could respond at high temperatures, increasing thermal insulation in cold weather.

Biomimetic Studies[1]

Natural materials in the animal and plant world have evolved over millions of years. We learn from the fundamental physico-chemical structures of skins, feathers, fur, hard shell coverings, actuators and bio-sensors, which control their effectiveness. Plant cellulose (wood and fibres) and control systems, which adapt in the environment, are also of great interest. Stomata controls the release or storage of water vapour in leaves which have already been simulated in materials used for wet-suits. The *DCTA* have examined two-layer mechanisms controlling the opening and closing of bracts in pine cones, governed by changes in atmospheric humidity. Layers absorb moisture at different swelling and bending rates, controlling vapour permeability and thermal insulation. Inflatable mesh structures and synthetic fibre piles mimic animal feathers, erecting or

[1] The abstraction of good design from nature

collapsing in response to changes in activity or temperature. Hence, climatic protection is provided in one layer - replacing several insulation layers presently used in military clothing.

Multi-Role Textiles

Mutli-role fabrics minimise the number of layers in Combat smart clothing structures.

Ballistic Materials

It is unlikely that there will be significant advances in future ballistic textiles, but performance improvements will benefit shapes and clothing constructions.

Skin Contact Materials

This is primarily a hygiene layer with the following properties: bactericidal, non-allergic, non-melting, high stretch & recovery, water vapour permeable, liquid wicking, flame retardant, quick drying and launderable - discussed in Chapter 10 on Medical Textiles.

Auxetic Materials

From the Greek "auxetos" [1] these materials expand in all directions. The DCTA are researching into auxetic polyethylene fibres which swell on impact, locking the threads in place for textile re-enforcement's in helmets and do not require cutting due to the natural 3-dimensional shape.

Intermediate Layer Materials

Layered materials combine the possibility of several functionals : -
thermal insulation, flame and melt retardant, ballistic protection and water vapour permeability.

Outer Combat Shell Materials.

There are many possibilities for integrated functionality, containing the layer which is important for multi-role protection. This *DCTA* composite textile include the following 15 attributes:- *wind and liquid proofness, physical durability, launderability, decontaminability, heat protectiveness, flame retardant, water vapour permeability, biological and chemical warfare resistance, electrical conductivity or anti-staticity, camouflaged in the wide spectrum encompassing : - near/far infra-red, visual, radar, acoustic.*

Future combat clothing systems could be based on several different concepts :-

[1] That may be increased

Onion Skin

The current 'Combat Soldier 95' "Onion Skin" layering approach, whereby eight separate layers of clothing have a specific function.

Future "Do-It-All" Space Suit

The ultimate 'Do-It-All' encapsulated *'Space Suit'* closed system is not favoured by the UK military because it is inflexible, too complex and expensive. The image is not politically acceptable and a patrolling 'spaceman' is too threatening to civilian populations.

Dial-A-Suit

The *DCTA* is studying automatic rapid scanning techniques for human bodies in order to provide anthropometric data and dimensions for automated garment sizing. This could be used to feed automatic fabric pattern-cutting equipment followed by automated computer controlled assembly of clothing items. Research in the Far East is currently solving problems of picking and placing flexible, dimensionally unstable fabric components in order to fabricate garments and has been described as "*The Dial-a-Suit"* concept. Future manufacture advances in protective clothing will also use the laser welding technique instead of needle and thread and improve sealing systems and methods of component attachments.

Head Carrier

Future military systems will incorporate significant amounts of optical and electrical technology mounted in the complex head area. This includes thirteen different interfaces between the human, the clothing, communications, sights, sensors and computer information technology and will all be a heavy weight burden to the wearer.

By integrating several functions, the inconvenient 'bulk' would be reduced by : -

i)	*Clean Air Supply*	=	Respiratory Protection + Microclimate Air Cooling
ii)	*Aural Sensors*	=	Hearing + Noise Reduction + Aural Communications
iii)	*Optical Sensors*	=	Visual + Near IRR + Far IRR + Information Displays
iv)	*Ballistic Protection*	=	Head + Eyes + Lower Face
v)	Clothing Items	=	Hood + Face mask + Collar + Helmet Lining

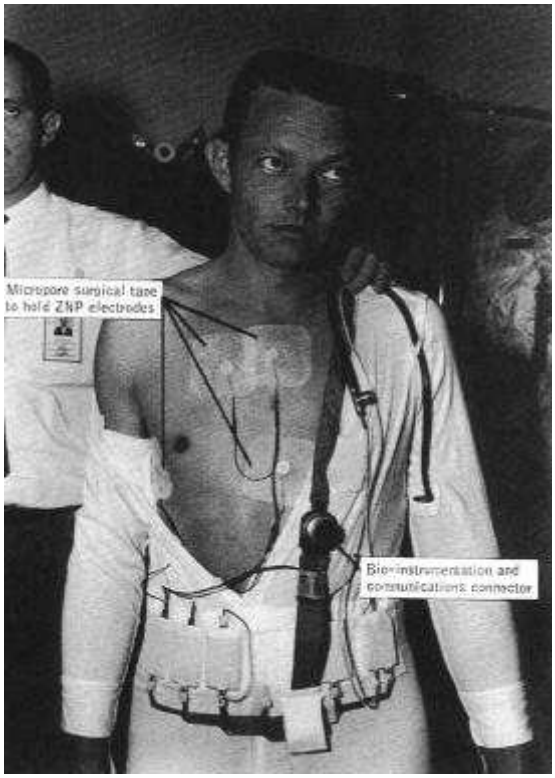
vi) Military Power Packaging

Electronic circuitry, computers, power supplies and control systems could be located away from the head and distributed over the body in organic, flexible packaging compatible with the human shape. This emphasises that our clothing is becoming smaller and closer to us - and will soon merge with us. 'Thin film circuits' built into the clothing systems would alleviate current bulky box-package problems on the body.

6.6 Space Age Technology

Bioinstrumentation

NASA[1] have been the pioneers in high-altitude, antiradiation clothing with built-in bioinstrumentation (ref. 48 and fig. 24). The need for stable, pressurised suits led early space-suit designers to automobile tyres, women's undergarments, leather and textile manufacturers and infant rubber toys and products, while engineers looked to medieval armoured suits for their articulated joints, used on the Mercury programme exoskeletons in the early 1960's.



[1] National Aeronautics and Space Administration
[2] A synthetic material woven into a filter

The Development Of The Pressure Suit

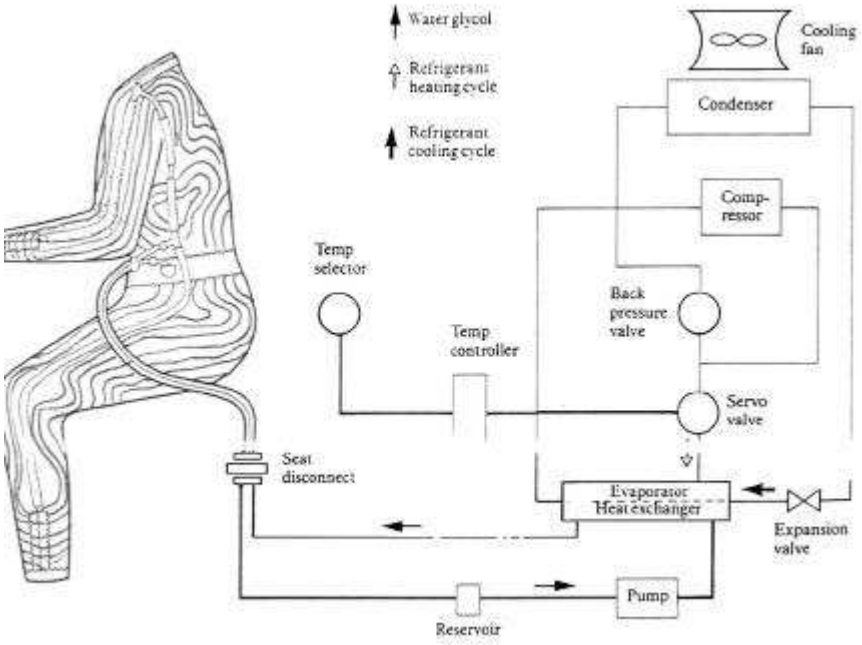
In the earlier space-suits, capstan tubing's were used to inflate and pressurise, tightening the cloth close to the wearer, thus withstanding the internal reaction of oxygen being forced into the lungs. In 1956 the tubes were larger, causing severe bulkiness, problems with weight, comfort, mobility and poor ventilation. The suit's system was still not fully automatically pressurised, although in 1958 a ventilation system was introduced throughout, distributing air in ducts. Earlier suits had used a separate undergarment for the vent system, whereby air circulation was assisted through a

system of triloc[2] patches on the underwear connected to fabric tubes, integrated throughout the suit. The air stream carried body odours, perspiration, carbon dioxide, water and other wastes out of the suit near the ear. Body thermal balance was maintained by the environmental control system and ventilation distribution. The suit fitted well without stress on body pressure points, with a proper waste management system.

In 1965 one-piece long johns with five pockets, containing biomedical amplifiers, were connected to body sensors relaying information to mission control regarding the astronauts pulse, blood pressure, breathing and temperature.

Original Liquid Cooling Suits

The liquid conditioned suit of the sixties consists of small pipes or tubes [1] enclosed in fabric tunnels, attached to the inner surface. Water plus ethylene glycol [2] enters through ducts in the wrists and ankles and flows centrally to the trunk, collecting in a series of outlet manifolds before returning to the supply system. (ref 48 & fig. 25) The flowing liquid absorbs body heat and loses it through a heat exchanger before recirculating through the suit.



The Extravehicular Mobility Unit

NASA's first complete Apollo lunar suit system weighed 81kg and was officially designated - *The Extravehicular Mobility Unit*. This contained the cooling garment allowing water to circulate through an interlacing of small capillary-like tubes stitched onto nylon spandex. This rested very

[1] Approximately 150 metres
[2] Antifreeze

near to the astronauts skin, cooling by direct conduction, almost eliminating perspiration. It was a lightweight, flexible, smooth, abraison-resitant, transparent PVC plastic, produced under the trade name 'tygon', used successfully in the dairy, food and beverage industries.

Supporting Life

The Portable Life Support System circulated oxygen, pressurised the suit, controlled temperature and contained a 'pump' for cool water. It also contained communication equipment transmitting medical data from the 'bio belt', with sensing devices distributed to body points.

Waste Control

The Waste Management was worn on the lower abdomen with tubing connected to a transfer valve, depositing the contents into the spacecraft reservoir. The solid containment for use when the suit was pressurised operated on the 'nappy principle', absorbing and retaining moisture while oxygen washed odours downward away from the body. **NASA** engineers would later supply the space-craft with on-board toilets.

Fire & Speed Control

The Integrated Thermal Micrometeoroid Garment protected against fire, extreme temperatures and from micrometeoroid impacts at speeds of up to 18 miles per second.

Space In The Future

Later Apollo's Space Shuttle *Primary Life Support System* suit components included oxygen bottles, water tanks, fan/water separator, pump motor assembly, sublimator, oxygen and water regulators, contaminant-control cartridges, sensors, communications equipment and this was all contained on the astronauts back in a backpack. In place of the liquid cooling systems a thermal protection system was based on heat exchangers to maintain an air-conditioned effect, miniaturising life support system, eliminating the necessity for the backpack and making it a future integral part of the suit.

6.7 Air Ventilated Suits

In tropical areas from 1957 air ventilated suits (ref. 49) were worn in many high performance aircraft, worn under pressure or as immersion suits. A mesh coverall supported a network of tubes, with air forced into them and out through small holes just above the skin, to keep the pilot cool and dry. The air supply is obtained from trapped engine air and cooled by a heat exchange. Contaminated air must be filtered through a bulky and complex filter which is difficult to install in modern military aircraft because it reheats cooled air supply. Figure 26 shows a photograph of a ventilated heating suit from 1980, illustrating the well-used technique of attaching tubes to fabrics.

6.8 Conclusion

Passive & Active Fabrics

Active fabrics as opposed to passive fabrics are the concluding evidence of a Dynamic Surface. Traditional textile design concerns passive issues relating to colour and texture (and performance purposes to a certain degree). However, this research project concentrates on a far more active approach to therapeutic textile design, introducing the living active garment as a second skin. Modern 'artificial skin' imitations with smart properties are becoming increasingly popular in the medical fraternity, with properties to boost the healing process. This will be discussed in Chapter 10 on Medical Textiles. In the following chapter the research looks at the *electronic pulse* in "Smart Intelligence" and its' relevance to the human heart and mimicry of the circulatory system.

Chapter 7

7 Smart Intelligence

7.1 Introduction

The Heart Of The System

It is furthermore important to establish the resemblance to the human body and exactly what *'smart'* intelligence means with relation to active clothing structures, function, comfort and desirability. By referring back to "The Triggers" in Chapter 5 and documented research discussed so far - it is necessary to state - as a *design-based researcher* - how 'intelligence' can physically be applied to futuristic clothing.

Smart Design

Smart Structures is a design philosophy integrating sensors, actuators, signal processing and control into engineering materials (ref 50). The meaning 'smart' can be used for fabrics because it crosses into many areas of science and design, and the concept is fast emerging as the next generation of dressing, or as a critical contributor to 21st century technology. Smart products respond to their environment, optimising and tuning their behaviour continuously. They offer many possibilities in civil engineering, product design as well as the fashion industry by enhancing functionality, improving performance and spanning field through aerospace, as well as offering protection through a multitude of danger warnings.

Environmental Sense

By establishing an acute awareness of how people sense and react to their environment we see how technology affects them. Smart materials give us the opportunity to investigate new areas of the human condition.

Previous applications include medical/health & safety wear, protective & military purposes.

Present and future applications for smart fabrics are illustrated in ‘Smarty Pants’ (fig 27).


SMARTY PANTS
Smart scent in 'Wellness' widens the possibilities of perfumery
Smart fabrics can 'self clean' by eating dirt and perspiration
Smart clothes will eliminate human error by 'self monitoring'
Smart fabrics literally have on going 'dialogue' with other fabrics
Smart clothes will enhance and provoke human behaviour
Smart fabrics are responsive to changes in their environment
Smart clothes can 'self' programme your correct fitting fragrance
Smart fabrics will detect 'ovulation' through the sense of smell
Smart clothes which 'feel' the crowd in a nightclub and respond
Smart fabrics have the capability to 'read' body states like a diary

Research In The USA

In March 1995 an opportunity arose for this PhD research to explore The Media Lab M.I.T.[1] and met Professor Mike Hurley [2] and PhD students, working in Virtual Reality, Interacting Sound Engineering [3] and Holography.[4] They were particularly interested in the concept of *Interactive Olfactory Surfaces* as this area had not (to their knowledge) been explored**.** Since then, contact has been maintained with The Media Labs, highly publicised rapid developments regarding *Affective Computing* achieved (ref. 51) as well as other 'intelligent bits and pieces'. During the visit to the States other Professors [5] discussed the possibilities of the research progression.

7.2 The Human Body

Bodies Are Smart

The human body - like smart structures- is a complicated and intricate machine. It is a masterpiece of engineering. Bones of the body form its supporting framework. The heart and veins are the *flow of life*. Muscles and bones work together to give movement in different directions - larger muscles giving strength for lifting and pushing, whilst small muscles allow fine movements. Elastic but tough ligaments link muscles to bones giving flexibility for bending and stretching.

7.3 Wearing Technology

Wearable Technology

Our technology is becoming smaller and smarter; it will soon *'blend'* in with us. Clothing devices are developing intelligence, with the wonders of incredible nano-*shrinking* 'implantable' computers and nano-tube systems. Evolution ends when technology takes over the body.

Lorna Ross of Interval Research Corporation California (ref. 52) says : -

[1] Massachusettes Institute of Technology, USA
[2] Prof Hurley, embroidery, etc
[3] Lisa Steifelman, Phd student, 1995
[4] Wendy Plesniak, Research Assistant, 1995
[5] Dan O'Sullivan, Department of Interactive Telecommunications, New York University

"*Wearware, is essentially an investigation into the potential of the body as a site for exploration and experimentation"*

Wearing a garment, whether it is fashionable, functionable - or not - is our most personal environment, an extension of our life, our moods, emotions and personalities. Wherever we go, this moves with us naturally. Wearing smart technology will link our senses, minds and souls to this external environment.

Body Layering

The multi-layering of technology and in the case of this project - *'re-cabling'* fabric structures - can be specifically designed onto the body within the disciplines of clothing design, causing new kinetic energy in active garments. Intelligent clothing must be unobtrusive and intuitive with beautiful tactile qualities, moving as naturally as possible. It is important to make the most or the 'least' out of intelligent clothing, ie: - to plan, select, conceal, organise, arrange, miniaturise, display, adapt, modify and eliminate.

Questions should be asked : -

What do we wear both inside and outside our bodies?
How do we carry things? How do we protect them?
How do we separate them?
How do we access things, which we put on and take off?
How do we access things which we cannot leave behind or exchange?
How do clothes fit or bodies?

A Body Of Fashion

Fashion Design consequently can be defined as ***Hard*** **or Passive Clothing,** for example, clothes which are purely functional, colourful and textured. Everyday we put them on and take off. ie: - shoe - collar - button - shirt - pocket - seam - jewellery - bag - spectacles - hat - underwear - coat - stockings - shirt - tie - jacket

***Soft* or Active Clothing,** for example, can be defined as the healthy and fit body which we live in (or the active living clothes) ie : - skin - muscle - bones - hair - the nervous and circulatory system - love - emotions - brain - lungs - language - heart - nose - eyes - internal organs.

7.4 "Things That Think"

Media Lab

The Media Lab has been known as a pioneer of *multimedia* over the past ten years, but according to media-guru Nicholas Negroponte[1] this mission has had its' day. A decade ago his vision was that a *brave new world* would redefine science, learning, media and entertainment. This is now being realised with the Internet, but they believe, in particular, that the World Wide Web and CD-ROMS are too common place.

Atoms & Bits

Negroponte splits his world into physical atoms and digital bits, (ref. 53) by claiming that :

> *"We know alot about atoms, we eat, touch, smell, eat, read, print.*
> *But we dont know much about the 'bits' and these bits, unlike atoms have curious properties."*

Sensing Feelings

This is the basis of Negroponte's lifelong research and subsequently the Media Lab are now more interested in 'giving intelligence' to everyday objects - such as a toaster, a pair of sneakers, furniture, windows, spectacles and musical instruments. A research consortium called **'Things That Think'** (ref. 54), based around the 'body area network' is currently researching into future interfaces for computing. By using the body's magnetic forces researchers transfer data between computers mounted in its personal environment - *in our clothing.*

Human Network

Central to Negropontes' vision is the use of the human body as the network that links the computers of tomorrow together which will become almost invisible to the user. Concentrating on *sensing* the movements or feelings of their owners, or even learning their owners habits, common household devices and clothing will soon be able to perform useful tasks using recent

[1]Director of the media Lab and Author of the best seller, "Being Digital"

advanced miniaturisation and microelectronics. Communication with wearable clothing-computers will be done through gestures. The Media Lab is consequently approaching new multi-national companies (who they would not usually follow for backing) in such areas as clothing retail, appliance manufacturers and food corporations, artistic fields, furniture and entertainment companies.

The consortium has been split into three technologies (ref. 55): -

1) **Sensing things** Developing new ways for formally passive objects to detect, manipulate, transmit and deliver information about their environment.

2) **Thinking links** Developing hardware and software for intelligent things to communicate among themselves and with their users.

3) **Understanding things** Developing the high-level senses required to make these objects aware of and sensitive to human intentions and emotions. Similar to this research project, the most important aspect is to understand the ways in which they interact with each other and with people, as well as their role in the broader social context.

Research examples currently underway at the Media Lab as of 1996 (ref. 56.57 & 58).

Magic Sunglasses which show you the way by 'guiding' you through the streets.

Patients Clothing which 'relay' health information directly to a doctors database.

Thinking Tables which accept instructions by tracking the users' hands in three dimensions. Used for navigating around 3D environments *Thinking tables* would subsequently *'see and react'* accordingly if your coffee cup is empty and the percolator needs to make some more.

Cello & Violin musical players which are 'sound controlled' by hand and body gestures or expressions and infinitely easier to play.

Business Cards which are communicated and 'exchanged' by the notion of shaking hands.

Night-clubs where the light and sound environment reacts to the dancing crowds.

The Wristwatch miniature telephone.

Shoe Pager & Video which keep its computing power in the heel of a trainer using body movement - as the most exploited part of everyday clothing. NIKE training shoe manufacturers are collaborating with MIT on this project to make it practical.

Digital Money as *'bits'* (on smartcards) and not '*atoms'* (notes and coins).

Carpets & Doorknobs which automatically open the door using a built in 'image-recognition' device and can also read the news for us by 'sending' information to our glasses.

Shirts will act as electronic door keys, informing buildings as to *who* you are.

'See & Hear' Computers with vision and hearing capacity only (no *'smelling'* - as yet).

Thinking Toys include a programmable brick with computerised power embedded inside, allowing children to build computation directly into everyday objects.

The Universal Remote is a small magic wand or 'remote control' working in conjunction with voice commands & body gestures. It also paints digital pictures or conducts virtual orchestras.

7.5 Quotes On 'Smart *Living* Structures'

Smart Structures Institute

Quotes from students at the Glasgow School of Art (ref 59), worked in collaboration with the Smart Structures Institute, University of Strathclyde : -

B*y implanting intelligence into materials, we could create a responsible technology, offering unconventional solutions to global problems like the generation of energy. Architecture could change and become an almost 'living organism' adapting to climate and inhabitants needs."*

Peter Janssen 1995

"Smart products embody many instinctive properties allowing them to learn by experience and therefore adapting to their environment, indicating their status through a pulse controlled with

smart steroids, with friction reduced via self-generated lubricants. Self-monitoring will eventually eliminate human error." **Scott Ferrier 1995**

"The need to communicate with others is all important in this age. We must communicate with the environment, in order to create a harmonious relationship by respecting our planet and its limited resources. Roads are the one physical link we have with all corners of the continent. A smart road network will grow like a tree, reproducing and fuelling further growth. Information will pass from cell to cell sensing traffic flow, environmental differences and learning to cope with new problems - thus creating a living smart structure" **Jock Gordon 1995**

"With all the advances in technology, the interface with the human body is still a difficult one. Applied ergonomics is a surface concession, the moulding of static objects to accommodate the contours of a continually moving human body. Invasions into the body space can be the most harrowing experience, involving pain, discomfort and humiliation. Can we use the opportunity, intelligent materials offer us to create a technology that acts in sympathy with our bodies?" **Jeni L**

"By sensing and reacting to their environment, smart materials can enhance our daily lives : - Windows and wall surfaces will 'breathe'. The quality of air within a structure could be controlled by materials which sense the build-up of carbon dioxide."

- Optical materials which react by changing their reflective index or shape could control the focal length in prosthetic lenses for cataract sufferers.

- In adverse weather conditions, road signs incorporating multiple layers whose reflectance and transmission properties, react according to temperature and humidity could change their information from speed restrictions to ice warnings.

-Filaments or petals which change shape or orientation could be used in filters, insulation or valves. Petal-like irises could replace a defective heart valve. 'Beating' filaments could transport debris. Filaments which change shape due to changes of temperature could be used between two layers of material as an 'active' insulation or be used in a heat exchanger.

- Materials which can be triggered to change between flexible and rigid states, could be transported flat, then triggered to stiffen when in use - for an emergency shelter, backboard, splint or 'hard-hat', reacting to the severity of the blow. Moulds which change state between soft and hard could be of great use in manufacturing, allowing for easy release in casting.

Stuart G. Bailey 1995

7.6 The Synthetic Age

Street deployment of *new smart fabrics* in the age of high-risk avoidance is where the goal of immunity against biochemical, biogenetic and bionuclear threats, forms the absolute futuristic way forward. Protection is therefore privatised and customised with chemical, genetic and computer engineering.

Magical molecular structures and invisible performances are consequently documented here using synthetic and natural properties: -

Programmable Nylon

Cyberutopians are talking about bioefficient self-cleaning, futuristic fabrics (ref. 60) which *'eat'* dirt and perspiration, which in theory *could* be possible using enzymes. Teflon-coated textiles do not absorb liquids so staining will be a thing of the past.

Iridescent Techno Clothing

Rave clothing now faces the test of other temperature extremes in a sidewalk paramilitary replay of the vintage astronaut suit's exposure to the high-radiation climates of deep space.

The 'Chameleon' Jacket

Designed around the nuclear pollution 'badge system' from 50 years ago, Dan Cooper at Salford University and his label 'Design Ethos" (ref. 61), have created a jacket that senses the amount of pollution in the air. Changing from a passive (petrol) colour to an aggressive (orange) colour when pollution reaches dangerous levels, the nylon based fabric senses three main pollutants : nitrogen oxide, sulphur dioxide and ozone.

The Elegant Mobile Telephone Glove

Designed by Lorna Ross [1] for discreet whispering calls and convenience.

"The glove phone (ref. 62*) will warm your hands while keeping you in touch:*

that taffeta-look skirt won't just ruffle as it moves - it will also play your favourite radio station. This is not the future . . . . we have the technology."

Susannah Handley Royal College of Art

'Interactive' Massaging Blind Date Waistcoat

Nicola Defrevre, a student from the Architecture Association (ref. 63), created a two-way partnership waistcoat which massaged the upper half of the body by interactively picking up 'memory' sensors from the other partner, when both at different locations.

Utilitarian Garments For Urban Survival

Garments which alert the wearer to acid rain or over-exposure to UV rays, the @tmos jacket (ref. 64) - designed around the needs of urban cyclists and carpets to guide people around buildings and anti-radiation carbon threads which shield against 'wicked' waves from computers and TV.

Smart Fabrics in France

At the Institute of Textiles in Lyon (ref. 65), chemists are developing materials which absorb the sun's energy to help retain body heat, and another that has anti-bacterial compounds grafted on it to slow down bacterial growth for operating surgeons. Michael Bourgeois, an engineering chemist, says : -

"In theory, you could have materials to help you relax, keep alert, give up smoking."

Liquid Crystal Colour Clothing

Global Inc. Hypercolour in London use liquid crystal in fabric dye (ref. 66). The metamorphic colour system changes colour with body temperature or the environment. Co-director Jonathan Sieff predicts 'fabrics and clothing could change texture or colour, according to your mood', giving body language a whole new meaning. On a previous visit to Global, in January 1995, Sieff was aware of research involving liquid crystal in Japan which is sensitive to *sound*, although no further reports have since been discovered.

[1] Ross created a mobile telephone glove for her MA at the RCA in 1994

Clever Musical Cloths

By knitting with a conventional material and conducting fibre connected to a sound chip, Dr Frances Geesin, a Textile Research Fellow at The Royal College Of Art, has created the first sensual musical fabric which looks like a knitted xylophone. (ref. 67) Geesin has also created interactive textiles which produce sound on staticity. She has worked with the disabled and greatly understood how their lives were improved by sensuality stimulating the senses. Currently she is concentrating on working with British dermatologists.

Optical Fibres Cloth

The Idaho National Engineering Laboratory (ref. 68) is carrying out research with optical fibres embedded in the fabric and fitted devices with the ability to measure blood pressure, body temperature and the presence of certain chemicals, giving feedback from body signals.

Sexy Stockings

Hosiery impregnated with vitamins, seaweed, aphrodisiacs and moisturising properties were briefly marketed by the fibre micro-encapsulation and cosmetic company Kanebo Japan 1987, (ref. 69) but were not a success story.

Untika

Untika in Japan have produced a 'solar powered' fabric made up from particles of ceramic materials. These are sealed into fine filament fibres to create a cloth which has 'positive' thermal mechanisms so that the sun's heat is stored within the garment.

Fever Reduction Fabric

Kobayashi Pharmaceutical Co in Japan have produced a medical textile called '*Netsusama Sheet'*, a gel-coated stretchable fabric to reduce a patients fever by 3 degrees centigrade.

Stress dependency

Stress dependant colour chemistry experiments were carried out at the University of Strathclyde Smart Structures Institute in 1994. This lead to adaptive carpets (ref. 70), which changed colour when you tread on the pile. The idea was unfortunately never picked up by any adventurous carpet manufacturers.

Memory Metalised Fabrics

This is an intelligent material with an enormous capacity for resuming its' original shape. The original discovery was based on specific properties in nickel and titanium (NT) known as '*memory alloy'* for military purposes (ref. 71). The alloys possess two distinct shapes which pass from one to the other according to body temperature and are imprinted with two shapes. These are then repeatedly taken from a very high to a very low temperature, to fix the memory, and are commonly used by *Warcoal* Lingerie whose brassieres *spring* back to the correct silhouette, no matter how many times they are machine washed.

Smart Circulation

Memory alloys are also used to regain original configuration in surgical tissue expanders, for collapsing, supporting and rebuilding veins and arteries in the body (ref. 72). Dr Tony Anson is an expert in 'smart materials'. His company, Anson Medical UK, has harnessed smart materials for a wide range of body implants using a magic staple with the potential to replace all the nuts, plates and bolts that make alarms ring at airport security.

Skin Cancer Protection Textile

Until recently dermatologists and cancer societies recommended that the body should be covered by suitable textiles. The misconception is that textiles provide total protection against the potentially harmful effects of solar ultraviolet radiation. This assumption is totally fallacious. Each year over 1000 Australians die, while two thirds of the population develop skin cancer. Professor Mike Pailthorpe at the Textile Technology Dept, University of New South Wales (ref. 73), proved that by using a textile with *UPF* [1] + 50 skin is less likely to develop tumours, whereas unprotected skin will develop cancerous tumours. The yarn of an ideal sun protection fabric structure is completely opaque to UVR radiation and the holes are small to avoid the 'hole effect'. The higher the cover factor the tighter the woven or knitted structure and hence the less 'breathable' it is. Research is underway in Australia to determine the UPF of a textile in a stretched and wet state.

Intelligent Sewing Machines

Professor George Stylios at the Bradford University Industrial Design Department (ref. 74) is a *smart* scientist who tailors technology to textiles, for such major films as *Jurassic Park*. He uses

[1] Ultraviolet Protection Factor

a Japanese *Pegasus* 'intelligent' sewing machine, with advanced sensors, fuzzy logic[1], genetic algorithms and a neural network. Professor Stylios says : -

"Every material has its own genetic code - the properties of the fabric". . .

His computer programme works to genetically engineer fabrics, predicting problems for design and complex sewing. He has also worked on intelligent clothing for "Blue-sky-projects" which change chemical and mechanical properties when moving from indoors to outdoor.

7.7 Conclusion

Science Fiction Fabrics

As with all technological advances, people will be sceptical, with many questions to ask. There is the element of 'fear' - (and excitement) - at the thought of hormones controlling cloth and fashion garments sprouting brain power, or that fabrics (in the case of medical textiles) will *grow* with your flesh as in many sci-fi movies. There are also the questions dealing with what people *really* want? Do they want to be surrounded by gimmicks and objects which think for themselves? Where is the line *really* drawn? How far can 'thinking technology' really travel in relation to fashion and textiles? Do we really want to be constantly under the control of technology and should we let the technology betray our intimacy?

Smart Mix n' Match

These are all questions constantly asked in the digital age of our time. Sensory Fashion is undoubtedly exciting, even if it is somewhat frightening to imagine more sophisticated nano-devices in the structure of fabrics, reading our inner emotions and switching or mixing fragrances and medication on & off, at the turn of a switch. Can this really be done? 'Mix n' matching' thinking technologies in a *re-cabled* interactive fabric could therefore make it be possible to blend aromas at your own will or mood state, rather like a children's chemistry set. Using an *electronic pulse* to drive the flow through tube systems, integrated into a fabric structure, it could be possible to have a whole range of different fragrances.

[1] A close-to-life thinking tool that belongs to the category of approximate reasoning methods, attempting to apply a human mode of perception and deduction rather than an electronic mode.

Chapter 8

8 The Electronic 'Pulse'

8.1 Introduction

Introducing '*The Pulse'*

This chapter will reflect on a number of subjects relating to the *human body* - the design of *delivery and tubing systems*. The chapter will finish stressing the importance of certain *Complementary Medicines* and available therapeutic products.

Biomimetic Beats - *The Good Design From Nature*

The Electronic 'Pulse' is the *live action pump rhythm,* pulsating continuously - as a life force - regulated at the necessary recommended pace through smart fabrics. Biomimetic Studies [1] prove that this *mimics* the human circulatory system, as do the majority of the worlds most valid creations. All natural materials in the plant and animal world have evolved over millions of years. We constantly learn from fundamental physico-chemical structures of fur, all types of skins, feathers, hard shell coverings, the human body, circulatory system, actuators and biosensors, which control their effectiveness.

Areas of research relating to the 'pulse' include : -

The Human Body - *the human heart, the flow of life, circulatory and nervous system*
The Pumps - *peristaltic pumps, vibrations, wave lengths, fibre optics and pulsation*
Tube Technology - *the heart of re-cabling systems for new smart fabrics.*
Controlled Drug Delivery Systems - *medical pumps, micro-porous laser holes, aerosols.*
Garden & Aquatic Equipment
The Science of Healing - Manipulative & Alternative Therapies

[1] The science of copying nature

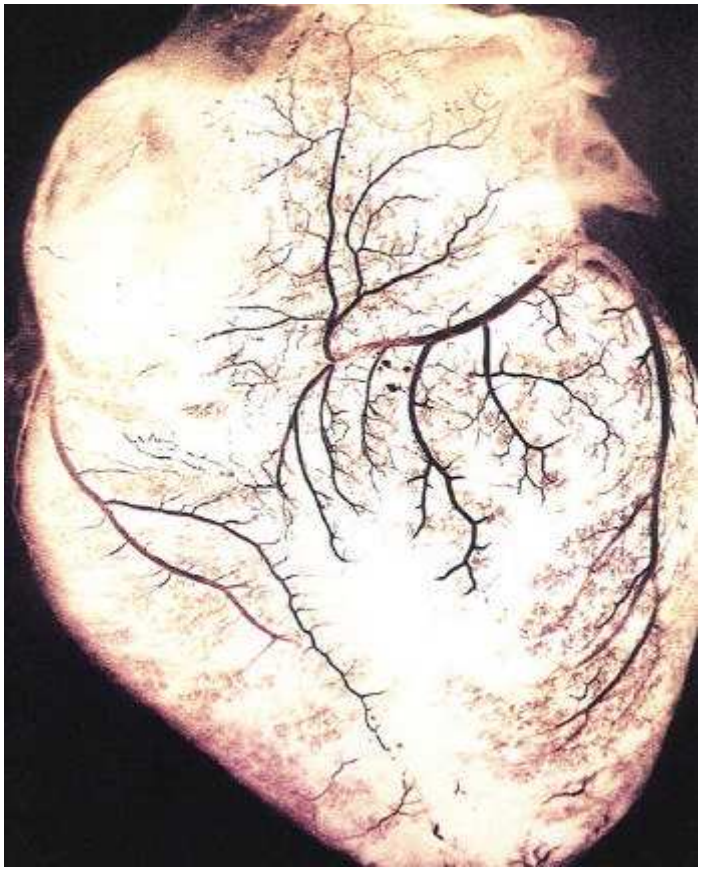
8.2 The Smart Body

The Smart Heart

At the centre of the human body's circulatory *transport system* is a marvellous organ which collects the blood and *pumps* it throughout the body for a number of reasons : -

- *delivery of food and oxygen to working cells to create energy.*
- *distribution of heat like the water in the central heating system.*
- *transport of building blocks for the continual renovation and repair of the body's cells.*
- *transport of hormones and other essential chemical messages.*

This organ is the **Smart Heart** representing the flow of life for humans and smart fabrics. (fig 28)



A Defence Mechanism

Compared with many man-made pumps the human heart is a marvel of efficiency, with its own power supply, control unit, pistons, personal repair unit and 'centre of feeling.' It is two simple pumps that beats as one, sharing the same control system. The blood carries two gases around the body - oxygen and carbon dioxide - along pulsating tubes, arteries and veins. The sounds of the heartbeat are called ***lubb*** and ***dupp***, caused by the different valves slamming shut. The second heart sound, 'dupp', is caused when the blood has been pushed out of the ventricles and the pulmonary and aortic valves slam shut. A single heartbeat is a simple process in which the right and left parts of the muscular heart work together and an electrical timing system controls the rate and directs the sequence of heart muscle contraction. Emotional behaviour, physical and sexual activity will affect it dramatically.

The Natural Pulse

With every contraction the heart sends, waves of blood are palpable as a pulsation travelling along the arteries away from the heart, becoming weaker as it moves away.

The Flow of Life

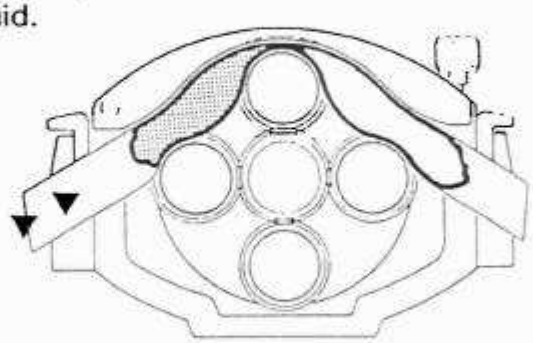
Blood is carried in large pipes and small tubes at the correct pressure only - whatever type of human behaviour is occurring eg : - fear, excitement, depression, anxiety, desire, elation. The delivery system has to cope with a continual stream of orders for different amounts of blood to be delivered over different distances, changing every moment. Too little pressure and the blood will be useless, too much and it could damage the cells it is trying to supply. Every part of the body has its own capillary system and it is here that the important work of the circulation takes place.

8.3 The Pumps

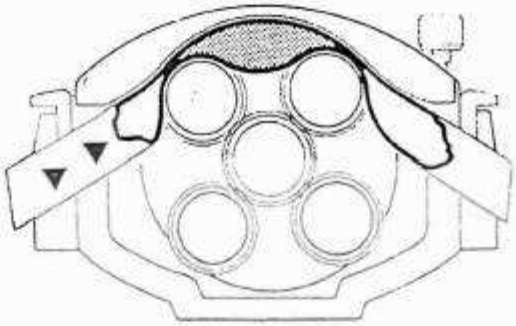
Where nature uses muscles, pumps use rollers to
sweep waves of fluid through an elastic tube (ref 75 and fig. 30).

Pulsating Peristaltic Pump

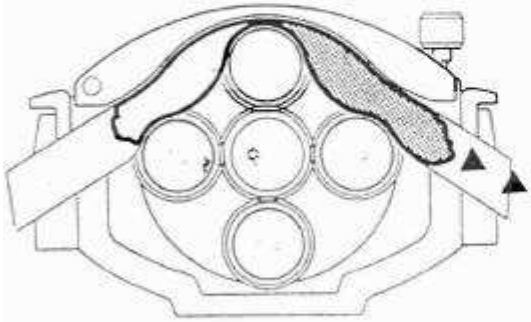
In the first part of the cycle, the advancing roller closes the tube which, as it recovers to its normal size, draws in fluid.



In the second part of the cycle, a pocket of fluid is trapped by the next roller.



In the final part of the cycle, the fluid is expelled from the pump. This is the peristaltic flow-inducing action.



Where nature uses muscles, pumps use rollers to sweep waves of fluid through an elastic tube. . .

The Electronic Heart

Peristaltic pumps imitate a human heart. They are unique in their operation as fluid does not contaminate the positive displacement pump and visa versa. There is no back-flow, no siphoning, they are self priming, can safely run dry and the only replacement part is tubing.

Peristaltic Pulse

Watson Marlow is one of the world's largest manufacturers of peristaltic pumps and pump heads. which are used for fluid transfer, metering and dispensing for up to 10,000 hours (ref. 76). They are ideal for pumping shear-sensitive fluids, sludge's, slurries, viscous fluids, aggressive acids and caustics, providing a range of flow rates from microlitres to tens of thousands of litres per hour, at up to 15 bar pressures. Watson Marlow pumps are used in the precise delivery of a variety of fluids ranging from sterile body fluids to highly viscous and abrasive industrial slurries, as well as in demanding circles, such as chemical processing laboratories, biotechnology, pharmaceuticals, OEM applications, British Rail, hospitals, R&D in cosmetics, textile printers, automobile manufacturers, water and waste treatment and food processing.

Non Mechanical Pump

A team of engineers at the University of Washington in Seattle (ref. 77), have built a silicon prototype micropump with no mechanical parts, using a similar process as for semiconductors. The pump consists of a tiny chamber approximately 100 micrometers deep, connected to two valves. One channel 'sucks' fluid into the pump chamber and the other lets it out. By flexing a lid on the chamber, pumping occurs by squeezing fluids through the exit chamber, which fills up through the channel when the lid moves back up. The pump can move as much as 200 microlitres per minute and researchers are currently experimenting with different channel shapes and fluids, which could include the delivery in ink jet printers, a portable chemical weapons monitor for the military and an implantable insulin pump for small hormone releases into the bloodstream.

8.4 Tube Technology

"We are proud to have received the NASA Quality Award for our work in developing and manufacturing the tubing used in the cooling systems of space suit".

Adam Spence Corporation (ref.78)

"We have no knowledge of anyone pumping perfumes through tubing which should not be a problem as some tubing is suitable for transporting alcohol and medical fluids. Fluoropolymers[1] are chemically inert" **Peder Peterson Optima Scandinavia** (ref. 79)

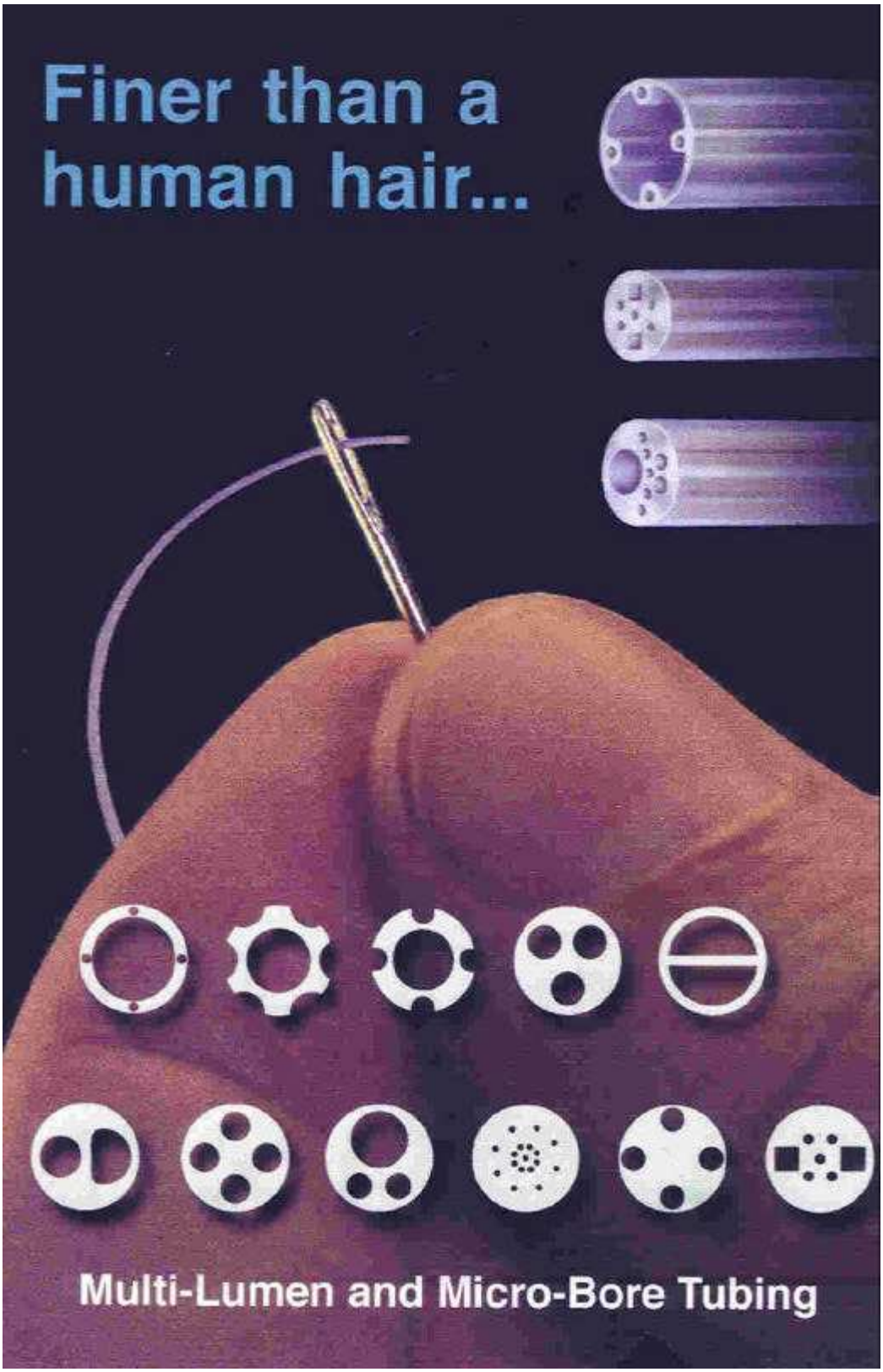
World Leaders In Tube technology

The latest in state-of-the-art *Development Device* equipment and tubular components are produced from a wide range of compounds - from polyethylene to Teflon. *Ever flowing* tubes must be kinkless, reinforced with a small bore and a smooth tissue-like outer surface. On-line computer monitoring assists in maintaining consistency and the quality of tube diameter. Throughout the extensive tubing research, speciality tubes by *Scanivalve* were found at a Trade Fair on *Sensing Devices.* Used for pumping fluids at high pressures these tubes will allow any flow delivery - even if an exceptionally tight knot is tied through it (ref 80).

International Tubular Leaders

As a pioneer of the extrusion of revolutionary resins, **Zeus** (ref. 81) have become world leading manufacturers of *heat shrink* and fluoropolymer *'super tubes'*, beadings, shapes and speciality wire insulation's. Zeus tubes are finer than a human's and used for non-invasive surgery to carry micro scopic lasers in the body (fig. 31). The company also exceeds the Military specifications for standard and custom products with over 30 years of experience, assisting with government agencies in revising specifications. Complex ultra-thin or heavy wall tubings deliver precisely what is specified to the closest tolerances. Another International company called **Adam Spence Corporation** specialise in the extrusion of major thermoplastic tubes including : *Nylon; Urethanes - aromatic and aliphatic; Poly Vinyl Chloride - soft & rigid; Blends / Copolymers / Alloys; Radiopaque filled ie: Barium, Bismuth, Tungsten Compounds; Polyolefins; Fluoroplastics; Thermoplastic Elastomers.*

[1] A high-technology plastic engineered by DuPont in resin or pellet form



Applying Tubes

Applications for tubings vary widely, including Medical Technology : Anaesthesiology, Intravenous & Drug Delivery Systems, Catheter Tubing, Urological, Neurological, Neo-Natal, Cardiovascular, Flow Restriction and Control, Gas & Liquid Transport, Thermal Insulators, Laser Technology, Hybrid Catheter Sensors, Genetic Engineering, Protective Coverings, Tubing Reinforcements, Micro 'Hose Clamps', Thin Walled Containers, Cryogenics, Undersea Pressure, Commercial & Military Aviation, Aerospace Technology, Automobile Technology, Sterile Sleeving, High Pressure Tubing and Electrical Instrument Insulation.

Single & Multi-lumen Tubes

Multi-lumen tubes[1] can be extruded with various lumens, different designs to customer specification, sending fibre optics, for endoscopic, gastroscopic and similar medical devices. Samples of different lumens are illustrated in figure 32b.

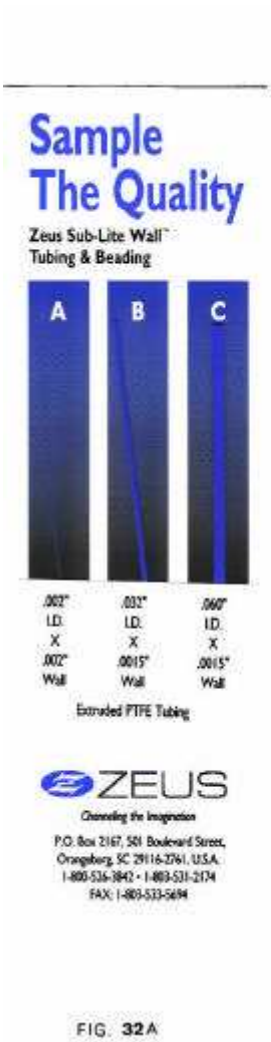


FIG. 32A

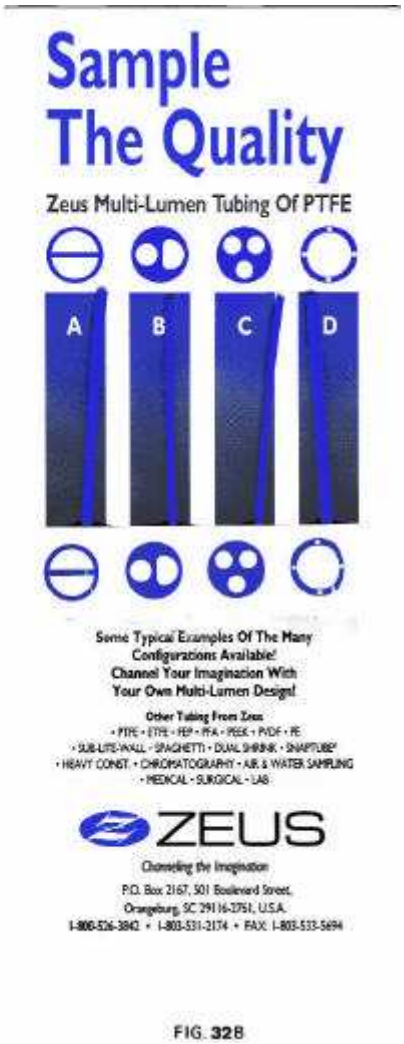


FIG. 32B

Coextruded & Striped Tubing

[1] Multi-channeled tubes

Radiopacity can be obtained by mixing additives such as Barium Sulphate, Bismuth Trioxide and Tungsten into the resin. *Optinova* in Finland have developed a technique to extrude the mixed material as stripes or layers into the wall of the tubing

Braided Products

Custom braided tubings enhance the performance due to the increased torque control, kinked resistance, burst strength, vacuum resistance, as well as the increased flow rate. Other examples of tubings include : *Miniature profiles; Coextrusions; Crosshead extrusions; Wall reinforced tubing; Multi-circuited; Jacket of micro wires and fibre optics and Pulsed tubing's.*

Micro-bore (from 0.001" ID)

"So miniaturised, it rivals nature's own capillaries" **Zeus Orangeburg USA**

Although it is possible to find tubes as small as 2 nanometres, the research has failed to locate this at present. The narrowest found tubings are *Zeus' Sub-Lite Wall,* micro-miniature fluoropolymer tubes, which have revolutionised medical, chemical & laboratory industry aspects. The featured I.D is as small as 0.001". An average dimension of a human hair is 0.003" (fig. 32a). Applications are used for collecting, diluting or infusing minuscule samples of liquids and solvents with incredible precision, helping solve plumbing and switching problems in chemical analysis and liquid chromatography. The micro-bore tubing's weight reduction, superior dielectric properties, space saving and compact advantages have put it in high demand with aerospace, automobile and computer domains. It is also the mechanically superior choice for miniature, solid or stranded wire applications, intravenous tubing, and it is possible to etch on the inside, outside or both sides, sliding easily into convolutes passages. The tubes are non-toxic, compatible with human tissues and fluids, chemically inert, stable, available for heat shrink applications and can withstand 500 degrees Fahrenheit and extremes of corrosion, shock and moisture. Micro tubes with lasers are sent through the body as well as as being used for open heart surgery and as micro components in computers.

Heat Shrink Tubing

Zeus Heat Shrink Tubing is another innovative line in which controlled stresses are created within the tubing walls, providing a skin-tight protective jacketing on components subjected to the most intense industrial environments. These include aerospace, chemical, electronic and medical environments - to nuclear, electrical and automotive. Extremes of heat, corrosion, shock, moisture and other hostile environments are shielded by advanced fluoropolymer properties including:

Component covering, Waterproofing; Mechanical & Shock Protection; Strengthening; Abrasion Protection; Corrosion Protection; Weatherproofing; Encapsulation Insulation;
Dust proofing; Sterilisation; Splicing; Cable Binding & Tying and Strain Relief.

PEEK Tubing

PEEK[1] is a phenomenal plastic engineered to withstand the harshest of industrial environments as it is insoluble in virtually all solvents, organics and inorganics, has excellent thermal and electrical properties, is resistant to radiation, ageing and shock and is resistant to high temperature hydrolysis. Industry applications include electronics, manufacturing, laboratory, medical, chemical, automotive, energy and aerospace.

[1] Polyethereketone

Dual Tubes

These are produced as a single unit of two independent tubes of similar or of variable sizes that stay together until separation is required and can be connected or disconnected. They are chemically inert, tangle-free, tough, durable and can be made from a variety of materials.

PTFE [1]Coated Wires

Round, flat, memory metal wire or twisted coated wires can be single or of a stranded design with other cross sections (fig. 32 a & 32 b). Coatings will increase the dry lubricity and are used for guidewires, core wires and stylets and have good adhesion, maintaining the flexibility of the device.

8.5 Drug Delivery Systems

Delivery Systems

Drug delivery by patient-controlled analgesia, transdermal devices[2] and other portable or implanted devices can be improved by adapting the therapy to individual patients, their particular symptoms and the changes over a period of time. Constant-flow drug delivery is a linear answer to a non-linear problem. For example, by overlaying two membership functions, which are- the recommended drug manufacturers dose and the symptom prevalence (appraised by the physician), relating to the importance of the symptoms exhibited by the patient. These could be the patient's age, body weight, blood pressure, glucose levels, nicotine, alcohol consumption & general physical condition. Iontophorentic battery controlled delivery systems use electricity small power packs, to aid transport across the skin.

GlaxoWellcome Pharmaceutical Development Division (ref.82) claim to be world leaders in inhaled and intranasal drug delivery for diseases such as rhinitis, hay fever and asthma. Medication is delivered using mechanical means relying on propellant driven aerosols, mechanical pumps for intranasal delivery and devices to deliver micronised powders to the lungs. In November 1995, when Dr A.P.Green [3] was contacted, GlaxoWellcome were researching into electronic devices for such applications, but were experiencing energy problems required to create droplets fine enough for delivery to the lungs.[4] The batteries and electronics were heavy, bulky,expensive and not as competitive as aerosol sprays, although they could forsee advances in

[1] Polytetrafluoroethylene
[2] Through the skin
[3] The Director of Pharmacy, GlaxoWellcome Pharmaceutical Development Division
[4] As small as 6 nanometers

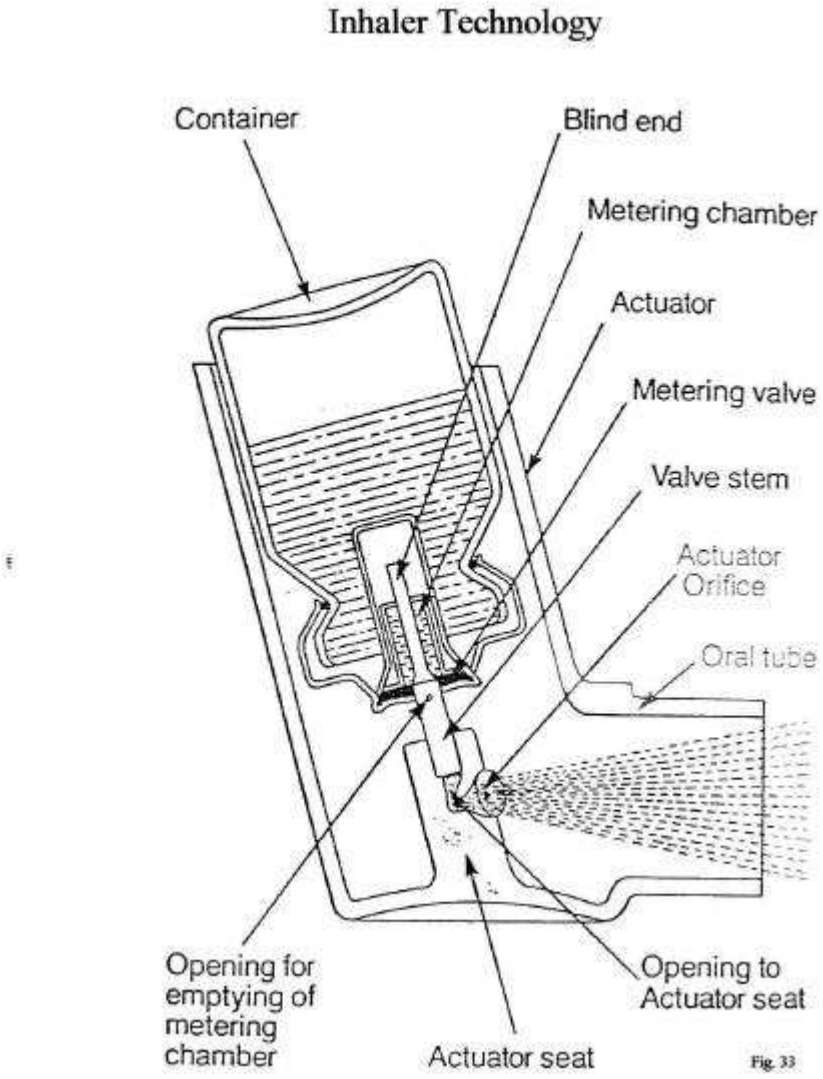
technology. GlaxoWellcome were also showing considerable interest in micropumps with biofeedbacks for diabetes and glucose sensors, providing the feedback loop.

Electric Capillaries

Capillary Electrophoresis is another area of interest relating to liquids in microbore systems. It is a rapidly developing analytical area which is likely to become extremely popular in 'drug delivery' development. The technique relies on using electrical charges to drive molecules through fine capillaries, effecting a separation of similar molecules due to small differences in charge and size. Dr Kevin Altria from the Pharmaceutical Development Division at GlaxoWellcome is a world leading authority in this technique, as is Beckman instruments who are the manufacturers in the equipment development

Atomisers and Inhalers

The Fisons Pharmaceuticals Respiratory Development Centre (ref. 83) are developing asthma products such as the infamous *metered dose* inhaler technology (fig. 33). Others are primarily powders for eye and nose inhalation using liquid products, conventional dropper bottles and spray pumps traditionally sold in pharmacies. In December 1995 direct contact was made with Dr M.Shepherd, Manager of Fisons Device Technology, who discussed new developing atomisers, using small quantities of liquid through *nano*-size orifices at high pressure, creating small particles. He believed that this was likely to be the 'next generation - no battery' re-usable, metered dose asthma inhaler, lower in weight and size, with cost advantages over the current atomiser systems under development.

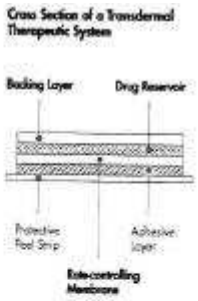


Drug Delivery

ALZA Corporation, a Californian based company (ref. 84), is recognised as one the world's leading product discovery companies in the development of therapeutic systems and the exploration of new technologies *(in vitro and in vivo)* to improve novel drug delivery technologies. The company is collaborating with many world leading research-based Pharmaceutical companies to further development, some of which include *American Home Products, Ciba-Geigy, GlaxoWellcome, Johnson & Johnson, Marion Merrell Dow, Merck & Co., Monsanto, Pfizer, Procter & Gamble, Sandoz, Schering-Plough, G.D Searle & Co. and Upjohn Animal Health.* The Irish company **ELAN Corporation PLC** are their main competitors in Drug Delivery, specialising in similar areas.

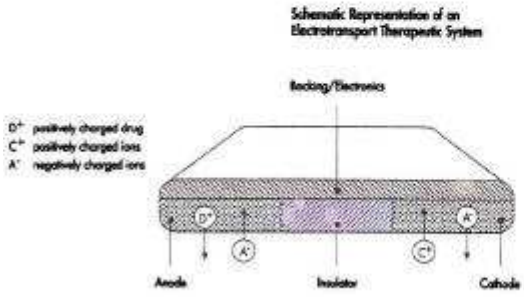
ALZA Corporation and **ELAN Corporation PLC** both incorporate drugs into technologies such as transdermal patches (fig. 34), which will be discussed in detail in Chapter 10 on Medical Textiles. As competitors, they are also independently developing infusion drug delivery technologies, oral osmotic tablets, dental fibres, *electrotransport*, eleastomeric, diffusional, pumps and implantable systems - all controlling the quantity and rate of delivering biotechnology compounds over extended periods of time. Therapeutic systems simplify drug therapy, increasing patient compliance by significantly decreasing the frequency with which medication must be administrated.

After the patient applies the transdermal system, the drug permeates through the skin and into the bloodstream at a regulated rate.



ALZA TECHNOLOGY

Transdermal Therapeutic Systems
&
Electrotransport Therapeutic Systems



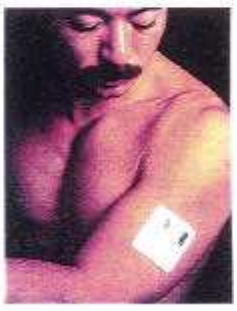


Fig. 34

Electrotransport Technology

Low-level electrical energy is being developed to assist the transport of drugs such as proteins and peptides across the skin**.** It suits persons who cannot take pills orally or use passive transdermal patches. *Electrotransport therapeutic systems* (ETS by **ALZA**) are thin, flexible devices with an electrical power source providing a small current through the skin, helping deliver therapeutic agents to the body (fig. 34). Because the electrotransport permeation rate is typically dependent on the level of precisely controlled currents drug delivery can be monitored to a degree not possible with passive transdermal systems. ETS technology also absorbs drugs very rapidly, compared to passive transdermal delivery [1] .The patient can also press a button to self-administer drugs in the disposable and reusable system. More than one drug can be delivered via a single electrotransport system.

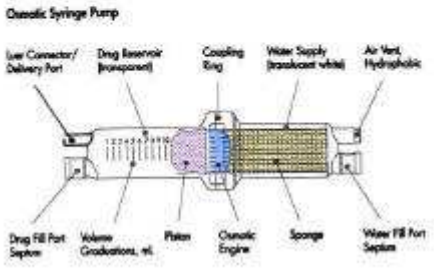
Medipad by **ELAN** (ref. 85) is a unique 'patient friendly' drug delivery system combining three approaches such as injection, infusion and transdermal delivery, helping to relieve 'needle phobia'. It is a small lightweight device, resembling a patch and adheres to the skin, with a range of delivery volumes.[2] Designed specifically for subcutaneous delivery the drugs are finely controlled in a continuous, pulsatile or a combined fashion. Within the device is a small reservoir, a probe, a flexible membrane and an electrochemical gas generator. By pressing a 'start button' mechanisms enable the probe to become exposed and penetrate through the outer layers of skin, whilst a small electrochemical gas generator produces precise amounts of controlled gas for delivery. It is low cost, minimally invasive, easy to use, with the capabilities found in expensive infusion pumps.

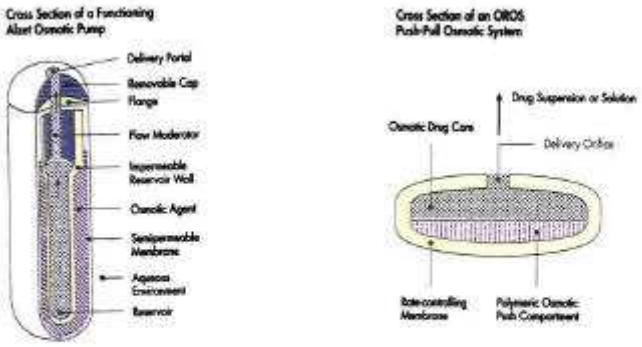
[1] Minutes as opposed to hours

Osmotic Pumps

Alzet Osmotic Pumps (**ALZA**) are implantable infusion pumps for use in laboratory research offering an economical method to explore the effects of rate-and-duration-controlled drug delivery of a wide range of agents, including peptides, growth factors, anticancer drugs, immunomodulators and cardiovascular agents. Targeted delivery of drugs to specific organs or tissues can be achieved by using the pump with a catheter, permitting continuous unattended infusion of solutions at pre-programmed rates for days or weeks at a time. In October 1995 this research project unsucceeded in acquiring samples of ALZA's osmotic pumps, used predominantly by scientists for 'animal testing'. Once modified, these minuscule capsulated pumps *could* successfully deliver fragrances and medication without micro-electronics (fig 35).

The Baxter Infusion is a light weight infusion system worn on the upper body





A selection of ALZA TECHNOLOGY **Osmotic pumps**, which could work as form of displaying fragrances, offering *continuous and precise delivery*. Small osmotic pumps measure 15cm and deliver medication up to 3 days. In these diagrams, once modified the reservoir could contain fragrances. Fig. 35

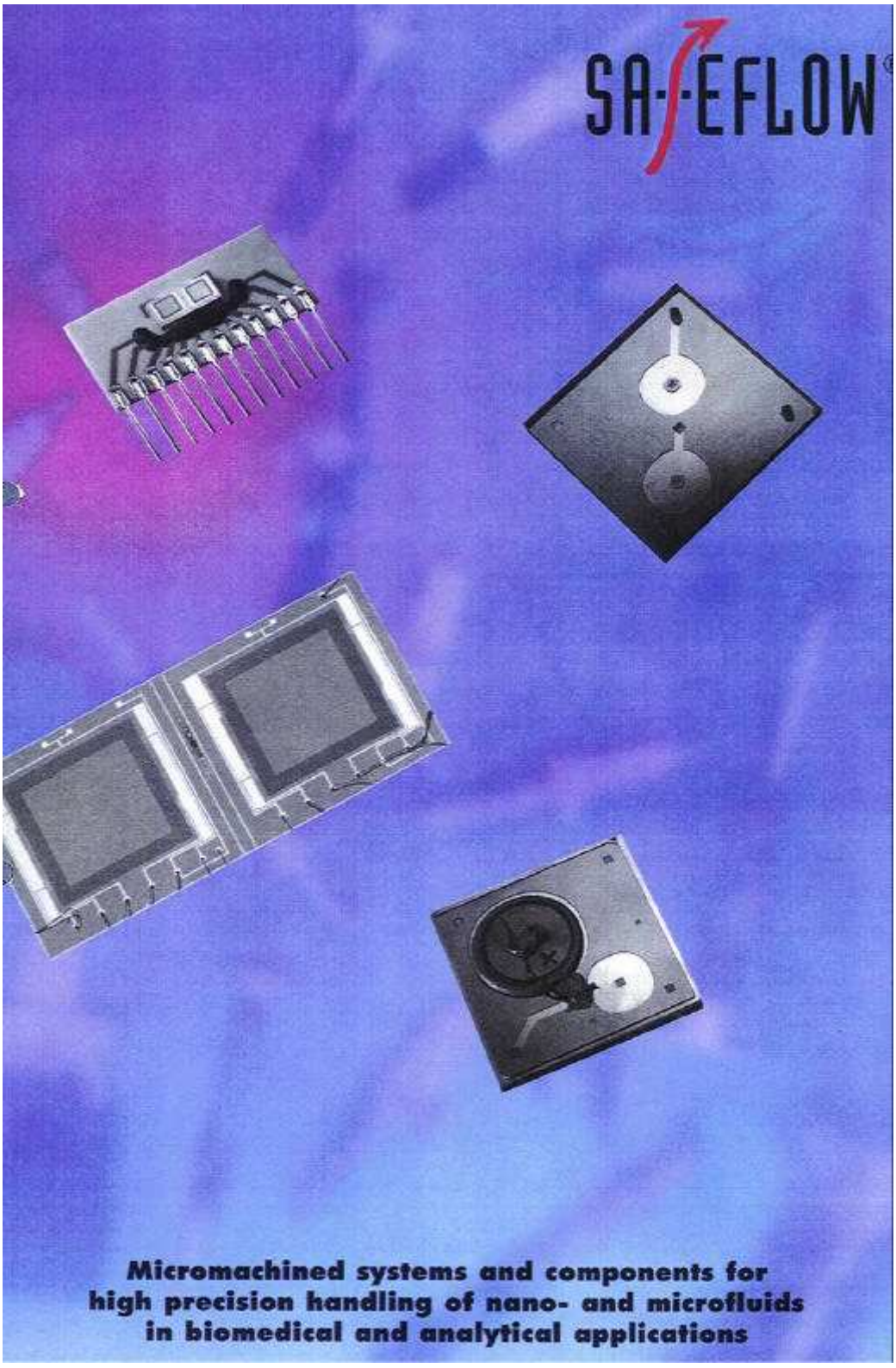
[2] 1,3 and 10ml

Parenteral Drug Delivery

ALZA's parenteral systems deliver drugs directly into the circulatory system or subcutaneous tissues and not by way of the alimentary tract. Products include *The Baxter Infusion* licensed by **ALZA** to **Baxter International Inc** (fig. 35). This is a small light-weight infusion system worn on the upper body enabling patients to receive controlled intravenous therapy and is suitable for administering anticoagulants, antibiotics, chemotherapeutic agents and other widely used drugs. Small doses of pain-relieving drugs are released when necessary into the blood-stream by the patient. ***ALZA's*** *Osmotic Syringe Pump* provides continuous precise intravenous or subcutaneous delivery of conventional drugs, peptides, proteins or diagnostic agents for up to two weeks (fig. 35). The disposable, wearable pump is powered by osmosis and contains a drug reservoir and separate water reservoir. Drugs are delivered independently of orientation, are easy to fill, economical and do not require electricity or gravity to operate.

MicroFlow Engineering SA and Ensyma SA

At the Institute of MicroTechnology University of Neuchatel, Switzerland, (ref. 86) micromachine systems and components for high precision handling of nano and microfluids in biomedical and analytical applications are engineered by companies called *Ensyma SA & MicroFlow Engineering SA*. They specialise in microfluidic applications for intravenous and respiratorial drug delivery. Exclusive patents are secured for microstructures, channels, valves, pumps and other biomedical *SafeFlow* microsystems (fig. 36) measuring 20mm I.D. They have **fitted** patents on microdroplet generators for breath flow controlled respiratory therapy devices, breath and particular signal processing methods, 'pumping' activated drug delivery systems and applications relating to non-invasive, or minimally invasive diagnostics in combination with respiratory therapy.


SAFEFLOW®
Micromachined systems and components for
high precision handling of nano- and microfluids
in biomedical and analytical applications

SafeFlow Nano Pumps

MicroFlow SA has also patented drug delivery methods on fuzzy logic circuits, specifically suitable for very low energy consumption knowledge based drug delivery control circuitry. They are able to build flow measurements and feedback controlled and microfluidic devices [1] with nano flow rates,[2] featuring an incredibly small flow measurement resolution. Micropump and multisensors flow temperature and pressure on one chip and are characterised for aqueous fluids. Specifications of nano-fluid handling is illustrated in figure 37, although MicroFlow pumps will be discussed in further detail in Chapter 9 on Delivery Experiments.

Fig 37

SAFEFLOW

Specifications

SAFEFLOW®, MEMS components and systems for nano- and microfluid handling

Flow control data:
0 to 50, 0 to 500, 0 to 5.000
and 0 to 20.000 µl/h
Flow rate increment: 50 nl to 300 nl/stroke
Max. pumping frequency: 20 cycles/sec
Min. measurable flow rate: 1 µl/h
Max. flow rate: 20.000 µl/h
Accuracy & repeatability: ± 1% full scale
Back pressure: 0 to 150 cm H_2O
Programmable fluid line occlusion detection

Fluid specifications:
Temperature: 10 to 40 ° C
Humidity: 30 to 90%
Fluid characteristics: pH 3 to 10
Viscosity: 0,9% isotonic saline, 5% dextrose

Components:
Piezo actuated micromachined pump, (pat.)
Micromachined multisensor for flow, temperature and pressure measurement and feedback control, 50 µl/h to 20 ml/h, other flow rates on request
Microprocessor based flow controller, analog or digital, PC interfaces available
Knowledge based microfluid dosage system. (pat. pending,
Microdrop/dropjet generators (5 to 500 pl/drop)
in cooperation with microdrop GmbH, Germany
Glucose, blood gas, other sensors from the IMT (see below)
Ensystemic ® engineering/design method.

Partners for Contract Research & Product Development

Institute of Microtechnology
University of Neuchâtel
Sensors, Actuators and Microsystems Laboratory

Centre Technologique
Jacquet Droz 1
CH-2007 Neuchâtel
Switzerland
Phone: + 41 38 205 121
Fax: + 41 38 205 711
Contact: Prof. Nico de Rooij

Micro- and Nanofabrication
Research and Pilot
Production facility for
MEMS, sensors, incl. chemical,
microvalves, actuators, biosensors
and other micro components

ENSYMA SA

Centre Technologique
Jacquet Droz 1, P.O. Box 46
CH-2007 Neuchâtel
Switzerland
Phone: + 41 38 205 161
Fax: + 41 38 205 753
Contact: Joseph Hess, Director

Benchmarking
Basic Engineering
Product Management
KBS Decision Support
Knowledge (Thinkware®)
based dosing circuit,
(pat.pending)

MICROFLOW ENGINEERING SA

Prototype development,
manufacturing and testing
Safeflow® concept,
Pilot and scaling-up
manufacturing,*
Contract micro-assembly*
(*planned)

Cooperation with injection molders, printed circuit board, Ti, 316 L or other housing manufacturers etc according to EN 29000 methods. Confidentiality guaranteed.

[1] From 50nl/stroke to 300 nl/stroke
[2] From 50(nano)ul/h to 20ml/h

On A Larger Scale - British Drug Delivery

Graseby Medical Limited (ref. 87) are popular British distributors of pumps. These include : -

i) *Portable lightweight syringe* drivers weighing 175g with an infusion range of up to 30 mins - 21 days. Speed range is variable, fixed or **pulsatile** with an advanced microelectronic circuitry, alarm system and safety cut-outs to prevent the drive motor overrunning. It is economical to run and can be used in the Community and General Medicine.

ii) *Syringe pumps* are the larger, electrical drug delivery systems in hospitals, weighing 2.4-3kg. The Graseby 3200 gives faster control of regular infusions, allowing safe administration of pre-programmed volumes of drug (i.e. 20ml at 4ml/hour) and infusions of drug volumes over a set delivery time (5ml over 2 hours) monitored on a screen and battery operated for 3 hours power.

iii) *Graseby 9000 Ambulatory* multi-therapy infusion pump for medication-on-the-move is designed for day and night wear by patients, with minimum disturbances to lifestyle, and is carried in a fabric pouch. It contains a wide range of infusion reservoir cassette sizes, offering extremely accurate drug delivery and comprehensive pump monitoring performance.

IVAC

The IVAC Patient Controlled Analgesia Management (ref. 88) is designed to improve acute post operative pain, encouraging mobility when battery operated for up to 6 hours. An IVAC P3000 Syringe pump administrates small volume infusions where maximum control of pressure is particularly important for maintaining precise delivery and protecting the infusion site, using standard size syringes.

8.6 Garden Equipment

Water Without Waste

Although the irrigation method of delivery is over exaggerated regarding size the principles are efficient and still apply to the delivery of a fluid, and in this case fragrances or medication. A "Micro-sprinkler' emitter scientifically controls the spray, making optimum use of available water over a greater area (ref. 89 & fig. 38iii). Sprinklers save energy at very low pressure systems, using mains water pressure so that no pump is required and they are perfect for farmers.

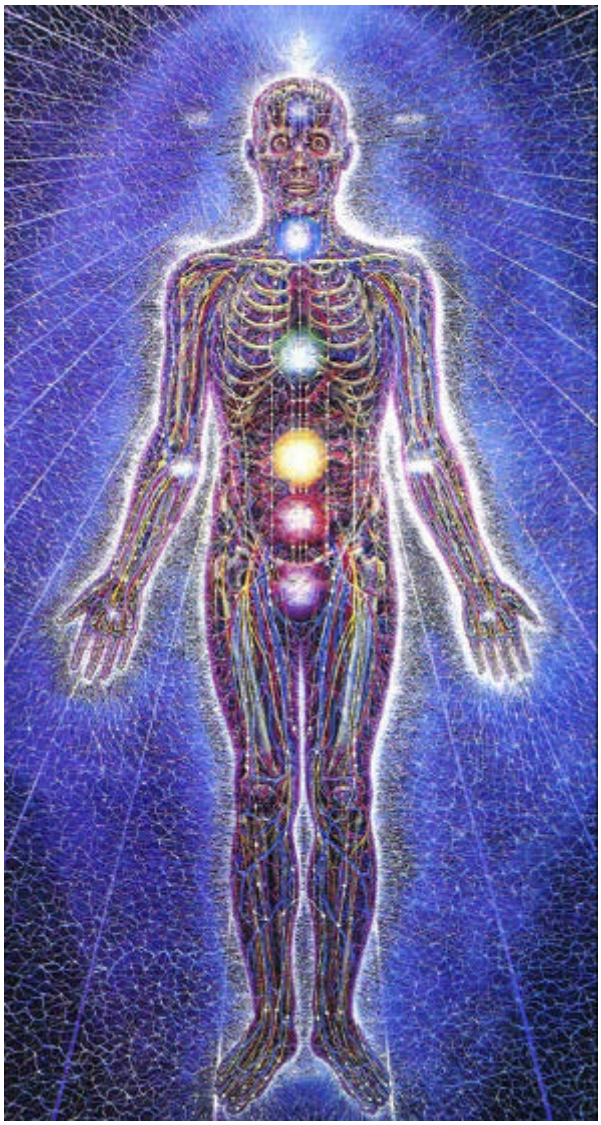
One of the world's most advanced lawn sprinkler's is the 'Whisper' by Zifir Agriculture (ref. 90 & 38i) which is virtually silent, computer compatible, tough and reliable and offers high speed water turbine drive for smooth as silk operation. Micro sprinklers are sufficient for green houses and shrubberies. Different precision formed nozzles spray upside down from pipes with a vapour mist to droplets, from close range to 36 foot diameter. The 'TIF' integrated drip line technology (fig. 38ii) controls field irrigation over vast lengths, illustrating extended fluid delivery in tubes.

Fig i. Computer compatible *Whisper* high speed water turbine drive lawn sprinkler
Fig ii *TIF* Integrated Drip line with special hydraulic controllers for field irrigation
Fig iii *Microsprinkler* spraying a vapour mist of droplets from close range to 36 ft diameter

8.7 The Science Of Healing

What drives so many to look beyond Western medicine for healing?

The "frontier" of *complementary, unconventional or vibrational medicine* enables the body to heal itself, with many examples of people being cured of ailments for which there is either no equivalent treatment in orthodox medicine, or for which treatment is too risky. The human body is a complicated, highly balanced equation (fig. 39). Changes in one area, tissue or system can upset the whole physiological balance, creating a variety of medical conditions including pain, tension, muscle spasm, poor circulation and venous/lymphatic drainage.



Stress Buster

It is estimated that stress is related to 90% of all illnesses and 82% of all industrial accidents with 90,000 people taking time off work due to stress.

Manipulative Therapies

In Britain the rising cost of back pain to the NHS is increasing – standing at nearly £500 million a year[1]. GP's give 14 million consultations a year for back pain but too often they are unable to help, which accounts for the employment of Chiropractors and Osteopaths in their practice. Both are holistic and base their work on the premise that the body has the capacity to heal itself so long as everything is in the right place. Both use manipulation of the joints and massage; neither use prescription drugs. Chiropractors work with joints, believing their approach is more diagnostic (disputed by Osteopaths) because they use x-rays. Osteopaths tend to work with massage and treat soft tissue; but there is a huge cross-over between the two therapies and both are safe as long as there is no risk to manipulation of the neck vertebrae, which would restrict blood supply to the brain.

The motion of massage literally mimics a 'muscle', ... like a heart beat vibrating.

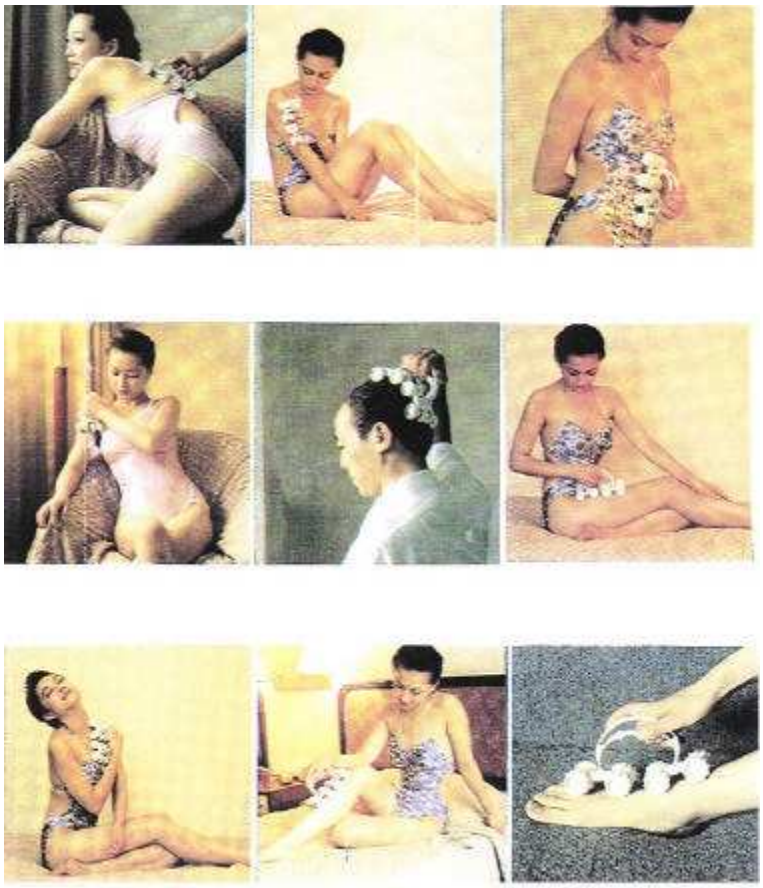
Massage Motion Relieves Stress.

Massage or 'bodywork' helps the circulation of blood by relaxing the muscles. The motion of massage literally mimics a 'muscle', like a heart beat vibrating. It comprises traditional Swedish massage, deep-tissue work, Rolfing, Asian massages such as shiatsu, reiki and reflexology [2] and 'energy' healings such as cranioscral therapy and therapeutic touch. Massage Motion can relieve stress and has been shown to stimulate the body to produce endorphins which help control pain, ease depression, anxiety, lower blood pressure and speed the healing of wounds.

Massage Products

Massaging products are not the absolute answer to underlying muscle problems (fig. 40 & 41). But they can, and do, bring symptomatic relief by alleviating the secondary symptoms associated with diseases and the ageing process.

[1] £3.8 billion in lost production and £1.4 billion in benefits



'Moon Craft Magnetic Massager' (ref. 91 & fig 40) draws on massage techniques using a wheeled magnetic *'rolling car'*. Without using electricity the 'car' is rolled in all directions, claiming to be very effective with the body surface, similar to manual manipulations in traditional Chinese medical therapeutics. The gradual 'rolling' movements combine magnetotherapy [1] with massage by pushing, pressing and tapping acupoints. It is constructed with style axles for all directions to clear channels, promote circulation of the vital energy and blood, relieve stagnancy, alleviate pain, cure muscle fibre inflammation and has been successful in various Chinese Hospitals and Acupuncture Clinics.

The electrically ball-rotating **PRO.SHIATSU** (fig. 41b) duplicates the kneading action of a professional masseur with instant relief from minor aches. With the aid of technology **Tsubo** (ref. 92) brings ancient skills of massage, using scalp, neck, reflexology, roller-storage, shiatsu instruments, ceramic heaters and magnetic fields to promote circulation, giving localised traction.

[2] Massaging the thousands of nerves in our feet, representing the body's internal organs
[1] Magnets stimulate the nervous system and improve blood flow through the body

Medical research since 1949 has proven that rhymical cycloidal [2] action produced by the unique eccentric motor incorporated into all **Niagara** therapy products ('Rolla-ssage' chairs, beds and massage pads with radiant heat for home, sports, professional and veterinary use. ref. 93) produces an elliptical movement like a gyroscope, creating 'cycloidial vibration' or *multi-directional* movement (fig. 41a). The result is a deep, relaxing penetrating massage which disperses tissue fluid, treats muscle spasm and stiffness, improves blood circulation, relieves respiratory congestion, increases capillary permeability, encourages lymphatic drainage, improves insomnia , decreases the need for tranquillisers - all with no side effects.

The **Viva** Aromatherapy Body Massager (ref. 94) is a electrically deep heat vibro-massager with facial, scalp, body and muscle applicator used over an 'oiled' body. **Thermopack** portable heat packs (ref. 95) can be recharged in a microwave or boiled in a pan of water but should only be

[2] Moving in a 3 way direction – north/south, east/west, and ina circular direction, all at the same time

used as a source of 'heat' on the body once 'cooled' again. **Hot Pot** uses no hot water and is a cotton bag full of oats which is placed in the microwave to heat. Similar to a hot water bottle, it is beneficial for muscular aches and arthritic pain. **Chattanooga** (ref. 96) Hydrocollator steam packs simplify the application of moist heat therapy, giving 30 minutes effective *moist* heat, and are re-usable by reheating in hot water. It is wrapped in a terry towel covering depending on the treatment area of the body.

Intra-sonic was first discovered to have healing properties in the 1920's. **Intra-sonic therapy** by **Novasonic** (ref. 97) is a compact and high-precision device, working by transmitting sound waves to the treatment area through a 'sound head', applied without pressure to skin. The direct consequence of each molecular impact is to create alternating compressions and dilation zones - a form of massage, but at cellular level deep within the treated tissue. This results in an immediate and demonstrable tightening of the cell-wall membranes, leading to increased blood circulation and improved metabolism. Since lymph, spinal fluids, cartilage, muscle tissue and especially bone all conduct intra-sonic pulses, the therapeutic consequences are significant, particularly in relation to joint treatment. Joints are encapsulated in sheaths of tough protective tissue and are most inaccessible to orthodox manipulative treatments.

Acupuncture

Acupuncture[1] relieves health symptoms which Western medicine cannot help (ref. 98) without the use of drugs. Stone Age people used stone or bone needles to scrape skin or lance abscesses and stimulate certain points of the body. Eventually they noticed these points lay on definite pathways and the sensation from the needle passed along a certain line, causing a distinct therapeutic effect. This was combined with basic anatomy - and the theory of *'channels of energy'* , was formed.

Energetic Life Channels

Acupuncture [1]is a complete medical system developed in China 5,000 years ago. It is based on the theory that the body consists of two opposing parts, Yin and Yang[2]. In good health Yin and Yang are perfectly balanced, but in illness this balance is disturbed. A diagnosis is made by taking a full history, noting appearance of tongue, colour and smell. The pulse is felt and 14

[1] Derives from the latin "acus"(needle) and "punctura" (to prick)
[2] Yin is deep, cold and female – Yang is hot, stimulating, male and related to the sun
[3] Imaginary lines on the body's surface

separate pulses can be detected, each one recollecting imbalances within the body. The Chinese believe that body organs are connected by invisible pathways of energy, so that illness in a particular organ may cause pain to be felt in another energy pathway or meridian[3]. The illness is caused by the obstruction of energy flowing along these 'energetic' channels and so strategic body points are pierced with fine needles, or massaged electrically. Once the treatment is complete the pulse is checked.

Magnetic Therapy

Magnetic Therapy has long proved to be a simple, powerful and painless method of dealing with many illnesses using magnets to stimulate the nervous system and improve blood flow through the body. However, it is not to be used in conjunction with heart pacemakers. Diseases which can be cured by treatment are called "Magnetism Deficiency Syndrome" It produces essentially natural benefits, with no danger of being habit forming and works partly by increasing the permeability of cell walls allowing the cells to release waste products faster, taking in nourishment more easily.

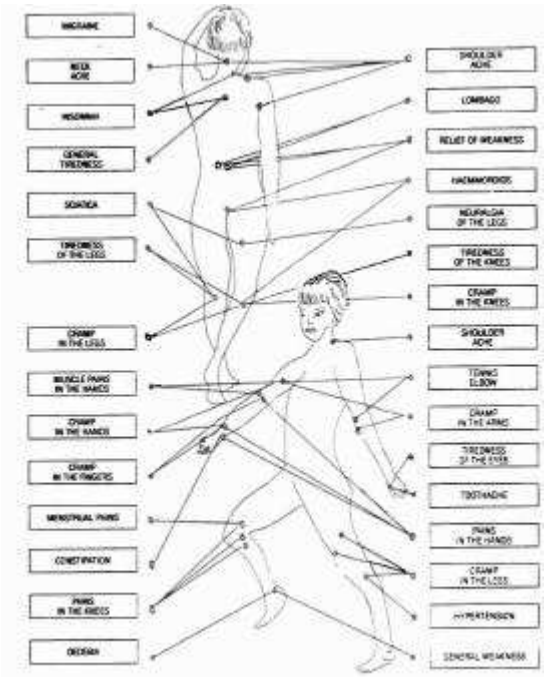
Natural Energetic Charge

The magnetic field also improves both the flow and quality of blood, increases energy, physical, mental and **subtle** levels, normalises blood pressure, activates iron content, reduces dangerous clotting, improves healing for bone fractures and scar tissues, generates spontaneous flow through the veins and capillaries, and assists with inflammatory conditions such as arthritis and neuritis.

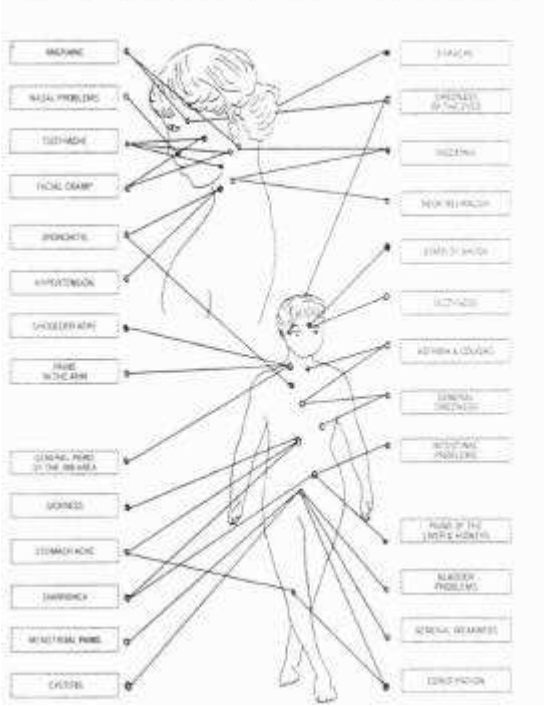
Magnetic products integrated into garments or accessories, placed on different parts of the body, improve the flow blood circulation (fig. 42). Examples include energy *necklaces* (ref. 99) to reduce tiredness, *plasters and bracelets* which are particularly effective in controlling blood pressure.[1] *Shoe insoles* have small raised magnetic discs designed to promote reflexology points, connected through the nervous system with body organs; *knee and shoulder belts* help arthritic and shoulder joints; *waist belts* alleviate lower back pain; *headbands* treat headaches; hairbrushes are effective in the treatment of excessive hair loss and preventing dandruff; *heel caps* are designed to reduce heel pain. Magnets should *not* be brought into contact with watches

[1] High blood pressure – worn on the right wrist and low pressure on the left

or plastic credit cards (using magnetic strips) and should not be exposed to water as they will become less effective.



The Magnetic Field Improves The Flow And Quality Of Blood



Polarity Therapy

Polarity Therapy (ref. 100) evaluates imbalances in the body's energy system and releases blockages with therapeutic touch, diet, nutrition, exercise counselling and yoga polarity. Once the blockage is removed, the healing power surges, expelling toxins, banishing mental fear and removing stress by balancing the body's *electro-magnetic energy,* so that glands and organs function better. The principles of energy, bodywork and composite healing philosophy are based primarily, but not exclusively, on Indian and Chinese systems.[2]

Spiral Energy

Unlike other bodyworks Polarity Therapy does not manipulate muscles or bones with hard pressure but works through the body's own energy systems, by placing hands on energy centres to redirect flow. It activates electro-magnetic currents that are spiralling in and around the body, working at a deeper level, harmonising and balancing energy in organs, the nervous system and the senses. This new electro-magnetism attracts Cosmic energy, making vortex centres in the body spin faster, balancing mind, body and spirit.

8.8 Conclusion

The Wellness Therapeutic Suit

At this stage in the design-based research *Wellness* clothing is inspired, designed and tailored around *The Science of Healing* through Manipulative & Alternative Therapies, as well as technology relating to orthodox medicine and drug delivery systems. Inspiration is therefore borrowed from *Acupuncture* when designing an all-over tailored body suit for the final graduating show (fig. 43).[1] This will act as the platform for sensors, tubing and micro delivery equipment, used to deliver fragrances as a basic demonstration for practical aspects of this research project. The suit also combines the use of 'thermography', illustrating warm and cool areas of the therapeutic body (hence the multi-coloured effect). The alternative therapeutic idea is to stress the meridian system, energetic network and magnetic fields, emphasising **well-being** and 'pulsating energy movements' evident in complementary medicine.

At the same time it is essential to stress the importance of : -

[2] Including osteopathy, naturopathy and chiropactopathy

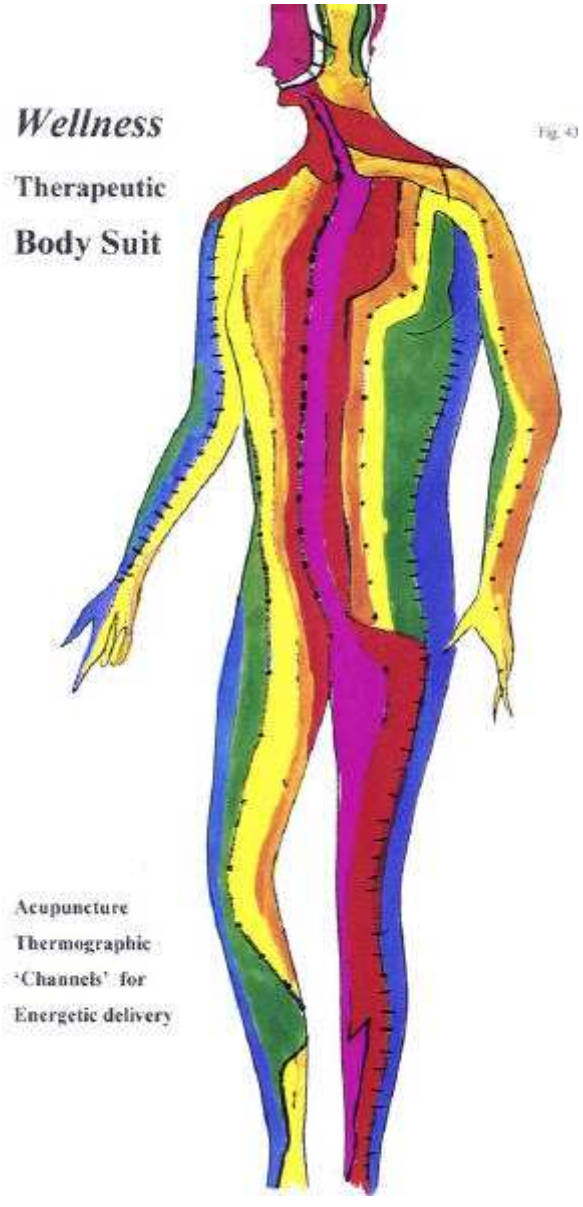
[1] RCA Part II Exhibition. 19 June 1997 showing a mannequin dressed in an interactive multi-coloured "Acupuncture Thermographic" **Wellness** Body Suit, displaying *controlled* fragrances from integrated tube and delivery systems.

delivery mechanisms for release

miniaturisation and micro-electronics

biosensors, responsible for the necessary required bodily interaction.

Having collected an enormous library of state-of-the-art information the following chapter will document ***'delivery'*** experiments undertaken at the Royal College of Art. Delivery experiments are separate to fabric and textile technologies and involve large industrial pumping equipment.



Chapter 9

9 Delivery Experiments

9.1 Introduction

This chapter stands as a practical illustration for the mechanical and electronic aspects behind 'fragrance release', by documenting various practical and theoretical experiments - including those which led up to the PhD. It will be separated into three parts, relating to the three years of research, but will not include any fabric samples attached to tubing, medical or industrial delivery systems. *Textile Technologies* will follow in Chapter called *Fabric Files.* The chapter will conclude with a selection of fashion designs illustrating **THE WELLNESS COLLECTION** and introduce the medical micro pump necessary for final experimentation.

9.2 Surface Design Of The Senses - Year 1 MPhil 1994-95

Constructed Textiles (Preliminary PhD Experiments)

Once it was established that *olfaction* was the primary concern of the research, small experiments were undertaken for *constructed textiles* which were very roughly illustrated using a wide variety of odd materials. The idea was to design the *inner core* of a smart *therapeutic* fabric by using any found material and converting it into a new structure. Techniques included paper engineering, sculpture, embroidery, micro-electronics and model making. Materials included bubble wrap, technical textiles, perfume sample bottles, wires, tubing's, medical adapters, stopcocks, wood, metal and cogs n' wheels.

9.3 Interactive Olfactory Surfaces - Year 1 PhD 1995-96

'A meets B. . . ' **(First Year PhD Experiments)**

The first year required extensive documentation for a state-of-the-art 'research library'. It was also essential to write a short, but explicit, *cartoon story*. This explains the interaction of two people meeting and the result of interacting 'smart' clothing allowing their moods to change for the better. The story (fig. 44 i - iv) fully illustrates how **The Wellness Collection** would act, react and stimulate (fig. 44 i. is a code to help understand the storyline). A second illustration also demonstrates how 'smart' clothing interacts with an individual alone (fig. 45).

Key

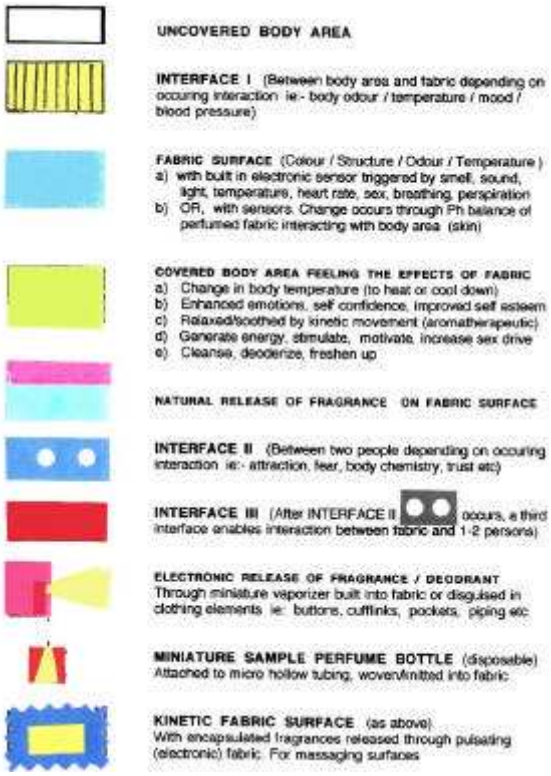


Fig 44(ii) - A meets B

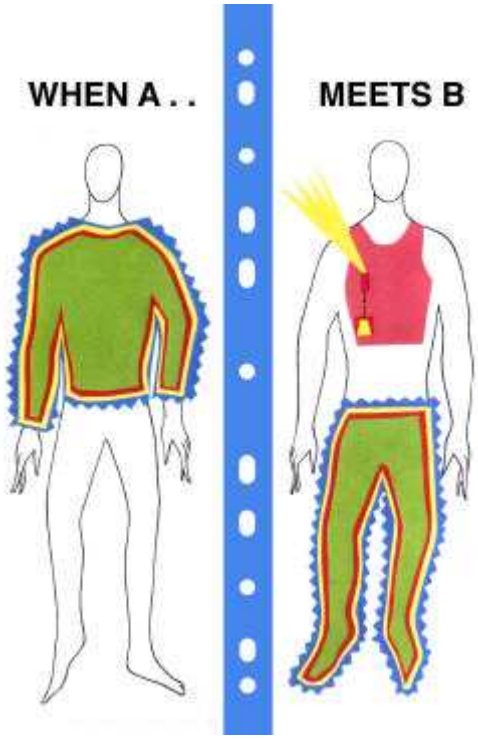
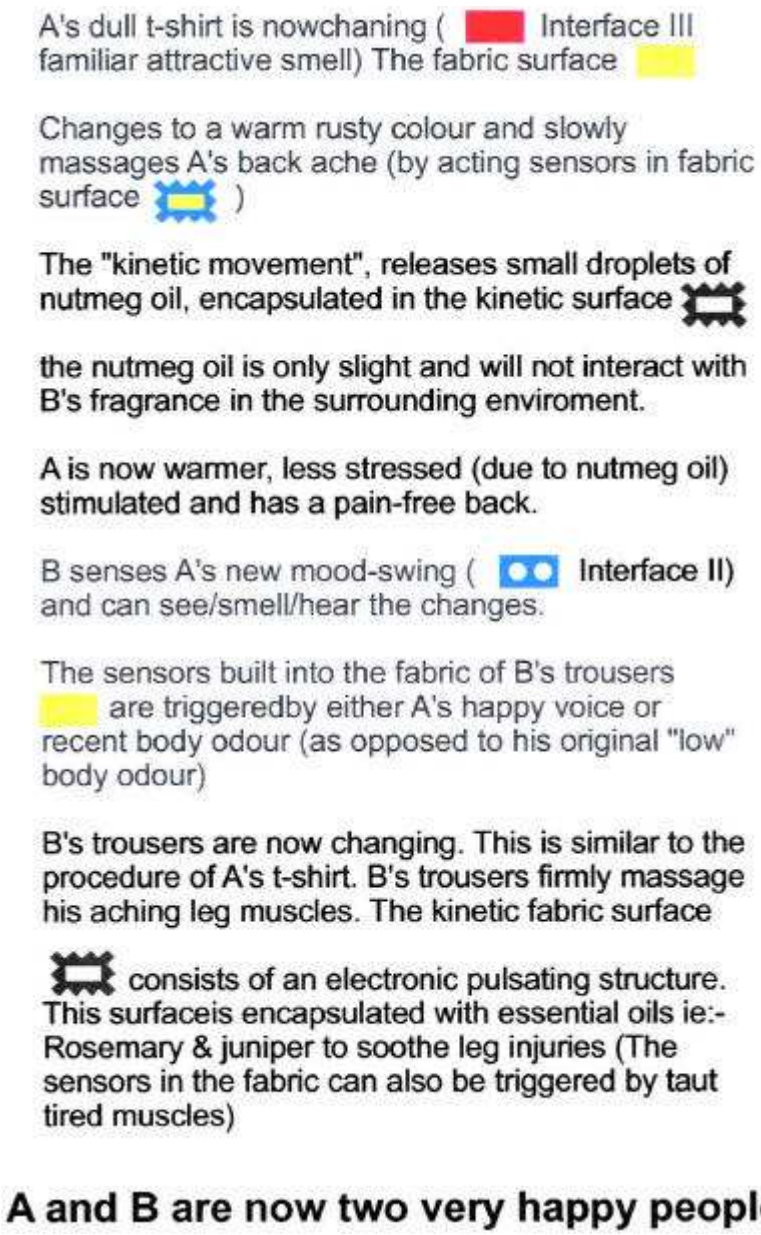


Fig 44 (iii)


WHEN A MEETS B
A is fed up and misses B
A suffers from severe stress causing back pain
A feels the cold and wears a dull t-shirt
B is outgoing, confident and very much in love with A
B is energetic, sporty, requiring leg massage for injuries
B feels good in Designer waistcoat and trousers
SUDDENLY... A meets B!!!
They know one another and "bond"
(Interface II recognition/attraction/familiarity)
The "bond" automatically triggers the sensors in B's waistcoat (activated by A's voice/smell) to electronically generate fragrance (contained in a small bottle disguised in garment) through a length of hollow tubing, built into fabric. The fragrance is released through a miniature vaporizer in
breast pocket. This is carefully monitored and controlled by electronic devices, attached to sensors in fabric (so as not to over do!)
A recognises the odour. This reminds A of B. A is feeling happier. The mood is consequently lifting and A feels safer!

Fig 44 (iv)


A's dull t-shirt is nowchaning (Interface III familiar attractive smell) The fabric surface
Changes to a warm rusty colour and slowly massages A's back ache (by acting sensors in fabric surface)
The "kinetic movement", releases small droplets of nutmeg oil, encapsulated in the kinetic surface
the nutmeg oil is only slight and will not interact with B's fragrance in the surrounding enviroment.
A is now warmer, less stressed (due to nutmeg oil) stimulated and has a pain-free back.
B senses A's new mood-swing (Interface II) and can see/smell/hear the changes.
The sensors built into the fabric of B's trousers are triggeredby either A's happy voice or recent body odour (as opposed to his original "low" body odour)
B's trousers are now changing. This is similar to the procedure of A's t-shirt. B's trousers firmly massage his aching leg muscles. The kinetic fabric surface
consists of an electronic pulsating structure. This surfaceis encapsulated with essential oils ie:- Rosemary & juniper to soothe leg injuries (The sensors in the fabric can also be triggered by taut tired muscles)
A and B are now two very happy people!

Go Medical Industries

The first fragrance experiment involved using basic medical devices form Western Australia. In December 1995 a *Go Medical Flow Control Tubing Springfusor* system delivered 10ml of diluted perfume every hour over a period of eight hours using a non-electrical, non-battery operated device. A further identical system delivered 30ml of perfume over 24 hours by using a different shaped nozzle and tubing system. The syringe was filled with diluted perfume, after having removing all air bubbles and attaching the device to an *extended flow control tube*. The original pump was only supplied with a length of 15cm tube, enough to deliver medication from a patients wrist to the elbow.

Jacket & Pump

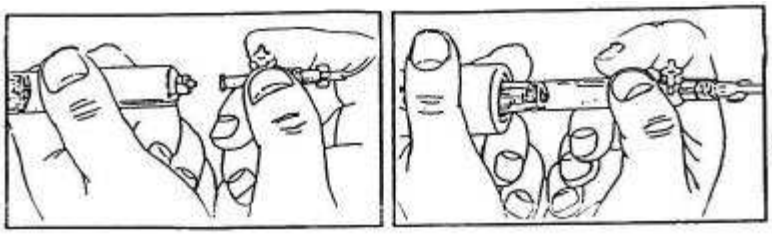
The pump spring system was crudely attached to the inside of a jacket. The *flow control tubing* was wrapped around and sewn to the jacket lapels and neck line and the nozzle placed at the collar line. Within 45 minutes fragrances could be smelt from the nozzle, as it emitted tiny droplets onto the collar. Despite the gadget's annoyingly obtrusive size this clumsy mechanism served the *very beginnings* of the research project's delivery systems, confirming that medical device technology is one of the possible answers for the research project.

Directions for using *Flow Control* Medical Springfusor 10

Ensure *flow control tubing* cap is screwed on firmly and push syringe plunger into seat of Springfusor. Position syringe flange in cut out of Springfusor, then lock into position by pushing down and twisting 90 degrees. Remove cap from *flow control tubing* and check that it is primed by waiting for a drop of perfume to appear and connect to cannula or injection port. Turn on tap to commence the infusion process. Fix Springfusor in position, for example inside a jacket, pocket, or on a lapel, pin it to clothing or shoulder holster and position the nozzle of syringe as close as possible to the same height as the injection site. Refill with a new syringe as this experiment will only work with the *flow control tubing* (fig. 46). Flow control tubing should not be used for more than 72 hours or for the same period as dictated by hospital policies for I.V administration sets. Re-use should be minimized to reduce the risk of contamination.

A further experiment involved a balloon pump driven reservoir which was unsuccessful. The pump device was attached to a small rubber balloon and a length of '12 hour tubing', measuring 30cm (Maximum time limit of delivery). The idea was that the perfume would be released from the pump at I0-2 minute intervals (lock-out time) but the experiment proved too small, fiddley and complex, despite a delivery capacity of 1ml per hour. Medical devices from *Go Medical* are

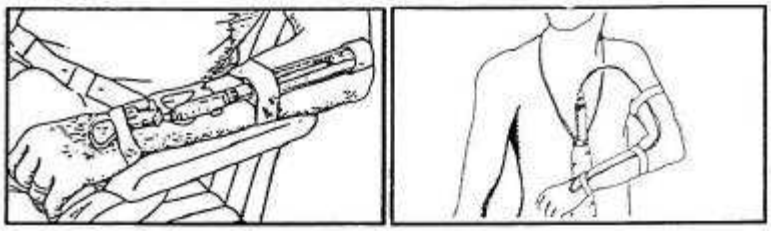
very basic, economical and primarily used in third world countries. Despite the simplicity of their products no interaction or control could be applied to any of these preliminary experiments.



1 2

1 Fill syringe with diluted fragrance and attach to flow control tubing

2 Push and lock syringe into *Springfusor* unit. This activates the time code (10 ml in 5 minutes)

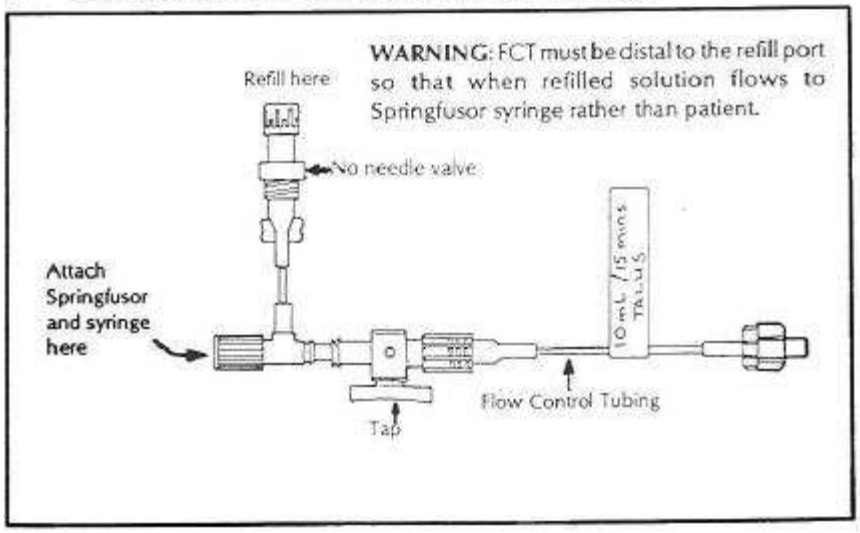


3

3 Attach tubing to where fragrance is required & *Springfusor* to arm, around neck or in pocket

4 Refill unit for fragrance 'top up'

4 **FLOW CONTROL TUBING WITH REFILL PORT**



Basic Experiment using non electronic device from **GO MEDICAL INDUSTRIES** Australia

Innovation At Brunel University

In July 1996 a visit to the Brunel Institute for Bioengineering and the *Tools For Living* department proved most inspiring. Engineers range from inventors to model-makers of the TV success story *Spitting Image*, such as Chris Chapman, head of the *Tools For Living* Rehabilitation Engineering Unit. The department is surprisingly open for a research unit, encouraging large companies and design graduates to promote innovative new products. Mr David Halls, a bioengineer, very kindly lent a device which he had specifically fabricated fifteen years previously to count blood pressure. The device is slightly larger than the size of a cigarette packet with a large protected built in reservoir holding up to 40ml of fluids. In the case of this experiment, perfume is injected through a small opening and remains safely within the reservoir. It is operated by a volt camera battery and 'sweats' fragrance at a rate of 2ml per hour from the small nozzle attached to microbore tubing. By hiding the device in a pocket, tubing was attached to clothing. Due to the unobtrusive size and weight it was not successfully possible to experiment too much with tubing in clothing, although the basic principle has been documented.

9.4 Interactive Olfactory Surfaces - Year 2 PhD 1996 - 97

Cross Sections (Final Year Experiments)

Theoretical illustrations of fabric *cross sections* for the Wellness Collection were designed as illustrated in figure 21 & 22- already seen in Chapter 6 on 'Dynamic Surfaces'. Initially they were designed by manipulating corrugated card collages into small kinetic structures which were subsequently photographed and photocopied with a repetitive pattern, to demonstrate a tactile 'movement' quality. Originally the idea was inspired by Issey Miyake's fabrics. Corrugated 'ripples' covering the surface emphasise how the fabric *could* give a massaging *well-being* effect, fully inspired by the smart military fabrics and biomimetic studies discussed earlier in this project.

Figure 47 illustrates a collection of four corrugated designs, exaggerated in size, to be viewed as *cross sections* through fabric. The final result (if ever fabricated) would be 40mm in depth.

Figure 47 (i) was constructed whereby 35 sheets of card are applied, loosely one on top of the other, creating a *wavy* 'multi-layered' effect with hidden pouches. These pouches represent a fragrance reservoir within the fabric structure. Fragrance travels through 'channels' within these layers and is displayed at 'release' points on the 'outer' shell surface of the smart fabric.

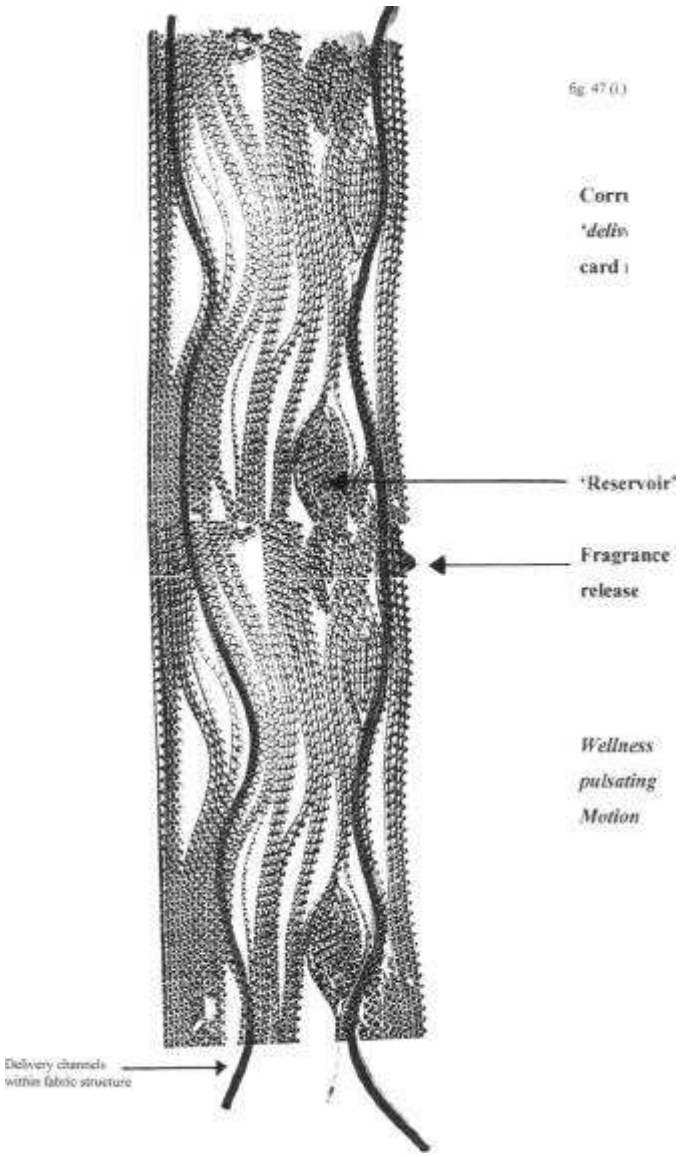


Figure 47(ii) was inspired by rotating wheels and a massaging product called the Chinese *Moon Massager* described in Chapter 8 on the Electronic 'Pulse'. The idea is to create a surface which, when activated, will lead the the 'inner-telligent' core of the fabric to control the 'outer' shell to give a similar effect as the wheels rolling up and down on the skin. Obviously, this concept is extremely complex as the wheels and mechanics would have to be *micro size.*

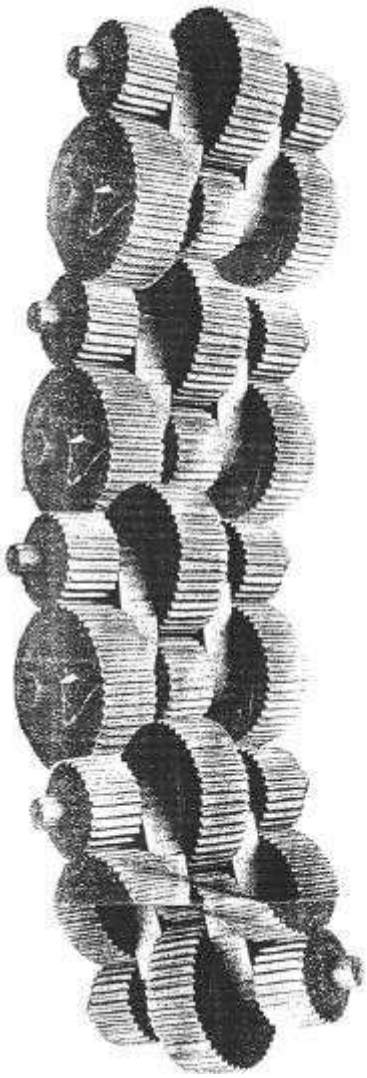


Fig. 47 (ii.)

Corru
rotati
card s

'cogs n' wheels'

Wellness
Massage
Motion

Figure 47 (iii) was inspired by biomimetic studies, pine shells, feathers and the gills on fish. Again, this uses the multi-layered effect although layers are concertinered together to illustrate movement and expansion, acting as a breathable 'smart second skin'

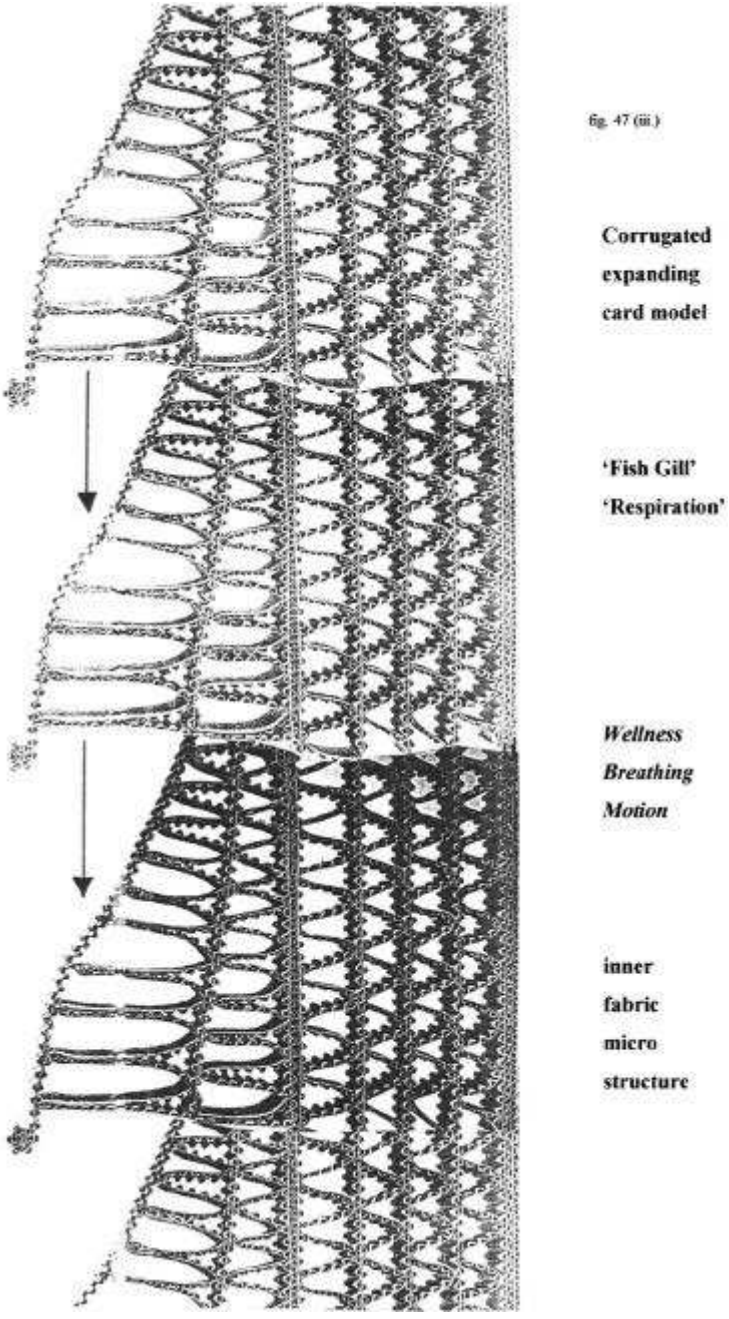
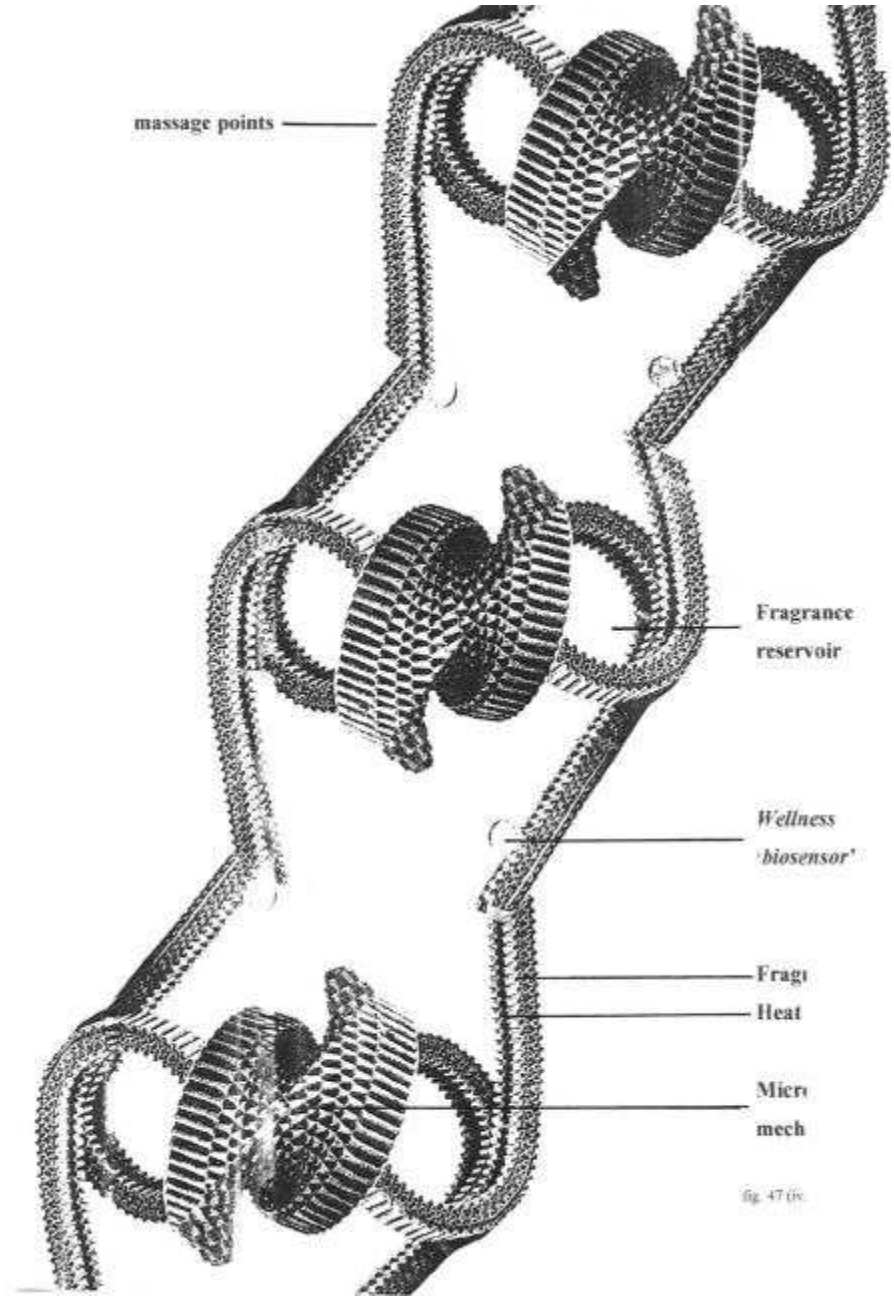


Figure 47 (iv) is an "unusual" collage for further massaging fragranced fabrics, using temperature and biosensors within the surface. The micro pump (eventually nano-size) would be contained and fully protected within the 'inner-telligent' core, controlling all actions.



Although virtually impossible to produce (at this stage in time) using modern textile technologies, the four collages successfully illustrate an **'inter-telligent'** dermis and **'outer-shell'** dermis of a *living dynamic surface.*

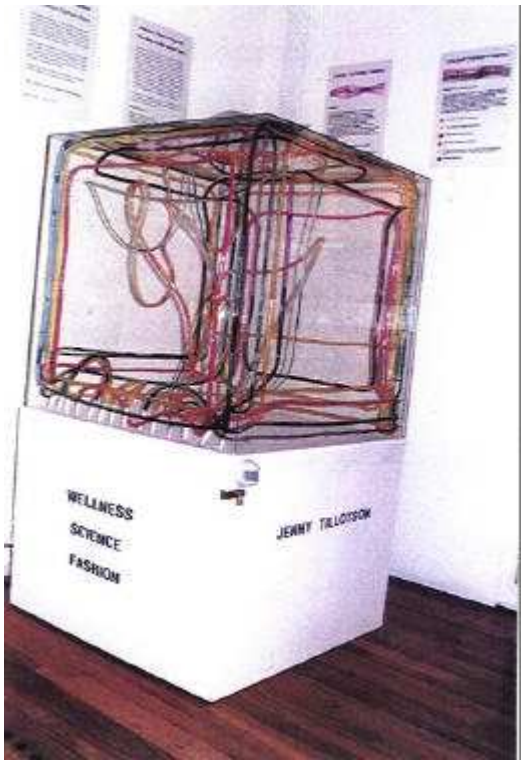
The most feasible method to put the diagrams into practice meant constructing an interactive *working 3 dimensional* installation. This coincided with the 'work in progress' exhibition.

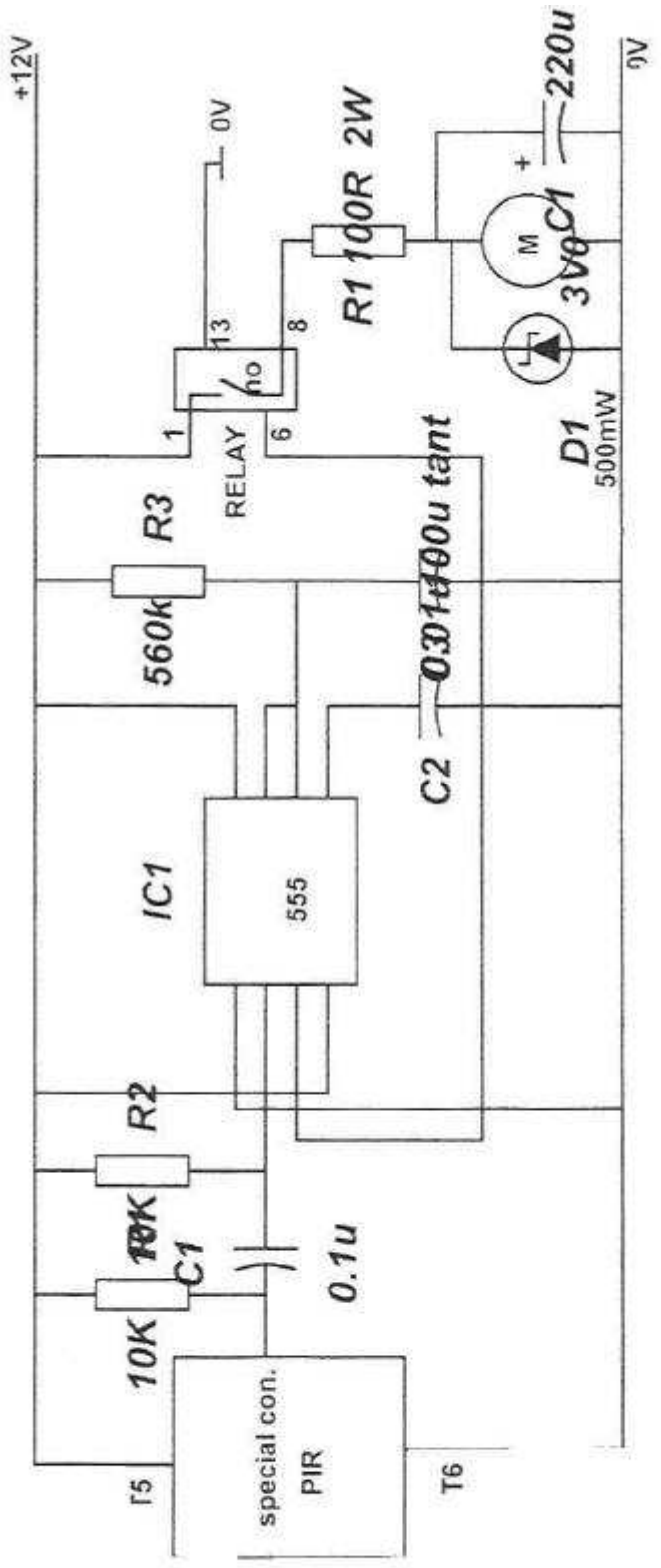
Work In Progress

Throughout the research process difficult bridges were *constantly* being crossed whilst trying to locate pumps, which were powerful and small enough to 'pulsate' small liquids, using exceptionally small bore tubing. However, it was decided that the most successful means to demonstrate the research was to 'exaggerate' the concept as much as possible in order for the 're-cabling, pulsating' network to appear *giant-size.* The method of *peristaltic pumping* proved the best source, as described in figure 30 - an invaluable industrial machine which imitates our *smart heart system.*

Wellness Smart Heart Fabric

An exhibition at the Royal College of Art in January 1997 demonstrated a *Wellness Smart Heart Fabric.* Using a large perspex box and decorating this randomly with a 'tangle' of six different bore-sized tubing's containing different coloured water, a *Watson Marlow* peristaltic pump *'pulsated'* and vibrated the liquid interactively when the exhibition viewer approached (fig. 48 (i.)). An infra red sensor was mechanically and electronically programmed and connected to the pump system by Spencer Childs. Figure 48 (ii.) illustrates the circuit diagram specifically designed for the electronic programming, in order for the pulsating 'on/off' effect to occur. The pump, a 505 Di series pump, contained a microprocessor, controlled with an alphanumeric display. Tubes were transparent and made from 'tygon' with a bore range of 8.6mm down to 4.6mm. Although no fragrances were released during this experiment the coloured water circulated around in the 6 different tube channels, with a chemical molecular structure of a *geranium* hung as a mobile above the installation, representing the *smell* interaction.





Circuit Diagram For '*Interaction*' Of The Wellness Work In Progress Exhibition

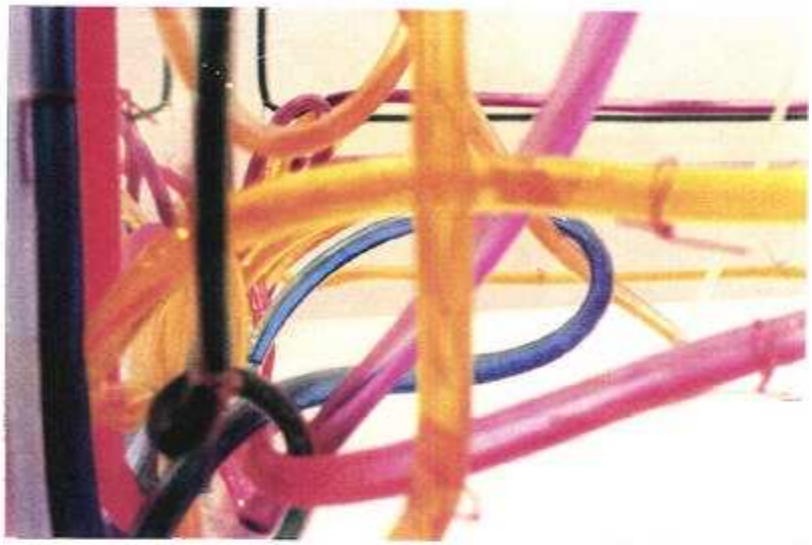
(Peristaltic pump connected to infra-red proximity switch) fig. 48 (ii)

Chunky Tubing

Watson Marlow pumps sponsored this particular project and although smaller tubing was deliberately not shown as an intrinsic part of the exhibition (due to aesthetic purposes and the necessity to illustrate large quantities of coloured water with chunky tubing) - other experiments included tygon tubing's with a bore diameter as narrow as 1.6mm. Each differing bore diameter demanded a separate pump head to accommodate the different quantities of water content. A total of 6 pump heads were attached to the pump and disguised in a plinth below the perspex box. The beating mechanic noises illustrated the movement and active life in a smart heart fabric, which automatically 'switched on and off' once the viewer approached (within a distant of 2m around the box at a 90 degree angle). Pump speed demonstrates differing levels of pulsation and heart beat speeds or pulse rates, although the exhibition remained at a constant heart rate of 80 beats per minute.

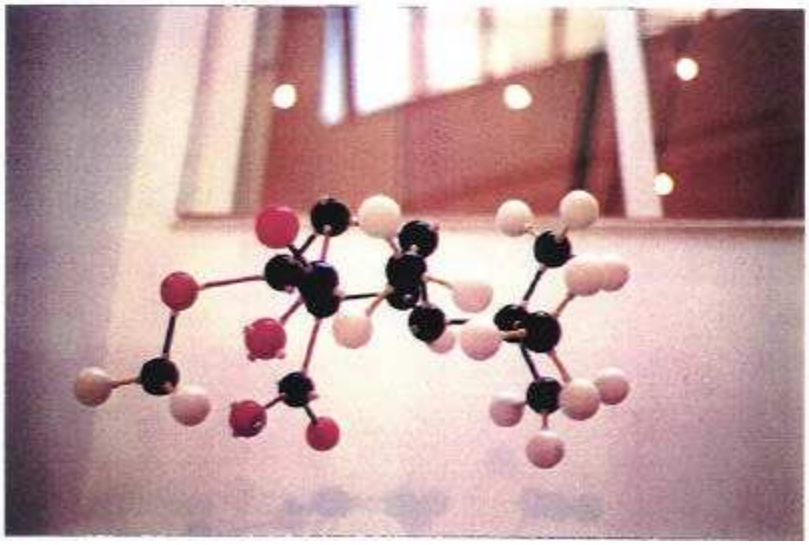
Tube Travel

The interactive 'work in progress' experiment and 'pump' demonstrated a human **'Smart Heart'** and **'Cross section living dynamic fabric'**. Coloured pulsating liquids illustrate: FRAGRANCES, TEMPERATURE, CONTROLLED MEDICATION & DIGITAL INFORMATION pumping around a smart fabric, and in the case of this experiment, the edges and surface area of a perspex box, with the smell of a geranium lingering above (fig 49).



Wellness Work In Progress Box

This experiment demonstrates a ***'Smart Heart Cross Section Living Dynamic Fabric'*** Pulsating liquids illustrate: Fragrances, Medication, Temperature, & Digital Information delivered through a ***tubing cable*** network-system integrated into an interactive textile. The molecular structure illustrates a ***geranium flower***, hanging above the *Wellness* box.



Tubular Mummy Body Suit

A visually theoretical experiment was inspired (but never carried out) by Professor Andreas Manz, head of the Analytical Chemistry Department at Imperial College, who kindly worked out the calculations: -

Length of transparent tubes - 10 metres

ID bore of tube - 0.5 mm

Atm pressure - 0.5

The result is 100 mm/s flow (2 microlitre per minute)

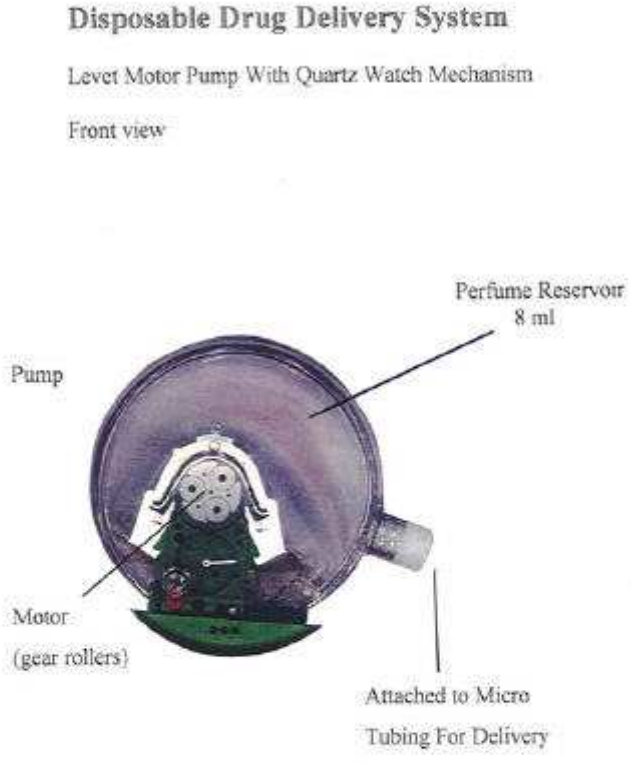
This would be far more of a *performance exercise* (purely because it lasts a few minutes) and was simply based on the principle of hydrostatic pressure and 'hospital drip bags'. By totally wrapping a human model in 10 metres of transparent tubing (*the body suit*) it could be possible to 'cover' a performance model in multi-colour(s). This worked by experimenting with smaller diameter tubing than already used for the 'work in progress' experiment (for example - 0.5 mm bore diameter) and hanging numerous drip bags of coloured water above the head of the model at an altitude of 5 metres (Like a very high toilet cistern). This is equivalent to 5atm pressure. Once a valve was opened to release the first bag of coloured water (for example - red) you could make the model look totally red - instantly. The model subsequently turned on another valve to change the *tubular body suit* to blue, followed by yellow and green. Changing from colour to colour would prove interesting, although a little messy as the water has to immediately drain into a tank standing behind the model. However, it temporarily gives the effect of colour rushing through tubing and changing from perhaps the colours of the rainbow and opaque to clear in a matter of 2 minutes.

MicroFlow Pump

In October 1996, as part of the continuing stage of the 'research library' process, various faxes were sent from the Royal College of Art to International Medical Device companies, requiring information and samples on micro tubing and medical mesh. The project was extremely fortunate enough to track down a Swiss company **Microflow SA** (as described in the previous chapter on 'Delivery Systems" in the Electronic 'Pulse') through the journal *Medical Device Technology.* Microflow were advertising micro devices for nano-fluid delivery. MicroFlow's Director, Joseph Hess, was pleasantly surprised and curious to receive a fax inquiry from the School of Fashion & Textiles at the Royal College of Art. Since then a relationship has developed with this research project, by way of using small disposable delivery motor pumps, attached to micro tubing and disguising or embroidering the tubing onto fabric surfaces.

Levet Pump

The motor pump (fig. 50 - front view & 51 - back view) is 60mm in diameter, rather like the size of a stop watch, and works by a quartz watch mechanism with gear rollers. It was invented by Monsieur Levet in Switzerland and is consequently called the Levet Pump, patented by Microflow. The pump is currently not yet available to buy commercially but can be used to deliver a variety of fluids. However, when an experiment was carried out to deliver a cheap after-shave the alcohol-based fragrance severely damaged the internal mechanism, causing it to block and break down. For this reason, experiments with non alcoholic based fragrances have since been used, such as rose or lavender water. In the near future it will be essential for the Levet pump mechanisms to be fully modified at the University of Neuchatel.



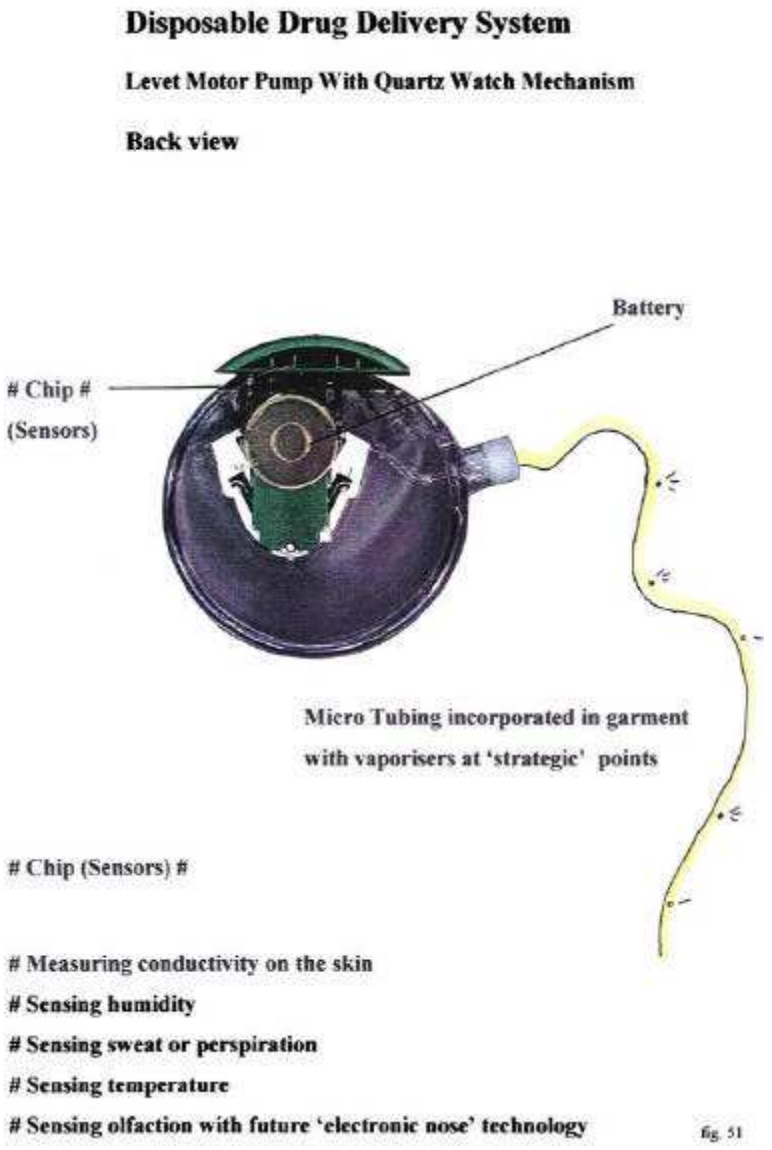


fig. 51

Peristaltic Pulse

The pump is disposable and can be thrown away after 8 days. Once the green cap is pressed, the quartz timer activates the gear rollers to work the micro peristaltic pump (similar to a human heart and identical to the much larger industrial systems, described in Chapter 8 on the Electronic 'Pulse' and earlier in this chapter for the '*work in progress'* exhibition). The pump creates a 'pulse' and rotary effect, activating 6 rollers to squeeze themselves against the micro tube inside the pumps core. Fluid - which in the case of this particular pump is usually a pain relief, such as

morphine for slow drug delivery - is therefore pushed in tiny pulsating droplets out from the large banana shaped reservoir through the pump mechanism.

Continuous delivery of fluid calculates at 1 ml every day with a total of 8ml over a period of 8 days, working out at 41.67 microlitres per hour.

As the pump is a simple system, it can only be triggered to pump when told so, by one (or more) attached sensors ie*: temperature, time, humidity, olfaction and the dispensing logic*.

It is therefore technically possible to connect a set of sensors to the pump in order for an *interactive* effect to demonstrate the true purpose of this project. In the long term these could be biosensors which would measure conductivity on the skin, sweat, perspiration, temperature and eventually could include an olfactory sensor as described in Chapter 5 on 'Triggers'. Body odour could therefore be 'picked up' from under the arm pits, sending messages to activate the pump and squirt out fragrances at the correct controlled time. Future modifications on this pump would miniaturise the system dramatically, making it more beautiful, flexible, inconspicuous, comfortable to wear and technically easier to apply devices and tubings to clothing.

Interactive Pump

At this stage, however, it has only been possible to connect the Levet pump to an infra-red proximity sensor, activating the system to 'start' and 'stop' when you approach. A further experiment includes coloured water (cake dye) which is injected into the reservoir with a hyperdermic needle. Rose and coloured water are displayed through the end of tubing which is attached to a pressure manifold, allowing various different channels to transport the fluid and widen the design limitations.

Tube Holes

It had originally been anticipated to drill holes at strategic points along the tubing using a technique from the USA called *Laser Microtools*, although this proved too expensive at the experimental stage in the research. Lasers are so incredibly fine they can drill or etch letters into a hair. The micro-tubes were carefully glued together using a micro nozzle. The adhesive was discovered at the Medical Device Technology Trade Show in March 1996. Loctite and primer 770 adhesive is a specific glue for medical devices and micro tubing. It sufficiently blocks any fluid release from around the joining areas or prevents the build up of unwanted glue residue.

Future Modification Research With MicroFlow Systems

On completion of the PhD it is anticipated that the electronics on the Levet pump will be modified. At this stage in the research project, it has not been possible to allocate micro/nano-sized manifolds which would contain a selection of different tubing's flowing in all directions around the fabric or clothing. When this is possible the device would pump into a micro manifold leading into several microtubes of different lengths, 'disguised' in the garment. These microtubes will have an outside diameter of less than 1mm. Each tube will be welded shut at the end and have a number of micropores at various locations which will be perforations made by a laser and have a size of 1 or more thousandth of a mm. The advantage of this solution is that the tube also becomes the nozzle as opposed to being the 'disguised' atomising button (or other clothing elements), and that by varying the number and the location of the micropores on each tube you can have the 'artistic' freedom to design and select where you want to dispense fluid (fragrance) on each tube. Consequently, it would be possible to dispense more fragrance via one tube than via another tube, as well as dispensing on different sites and different amounts through each individual tube.

9.5 Conclusion

This chapter concludes with a selection of fashion design ideas for **THE WELLNESS COLLECTION** as a 'second skin'. Figure 52 begins by illustrating a simple design whereby the Levet pump (representing the 'heart' of the fabric) is an intricate detail of the fashion design and the tubes are embroidered onto the fabric surface, mimicking the human nervous system.

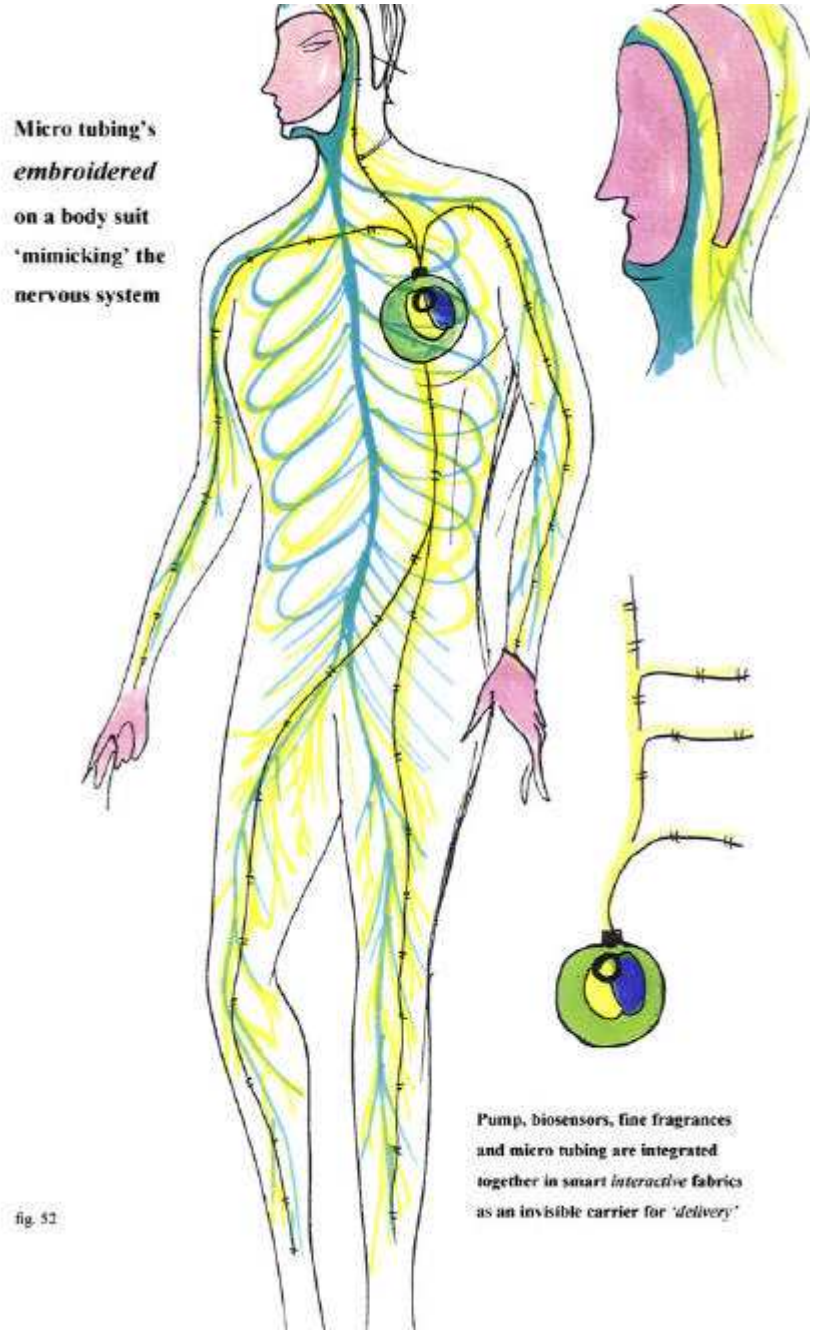


fig. 52

Figure 53 introduces the possibility of 'Electrotransport' monitoring incorporated in the 'inner-telligent' fabric structure (as described in the previous chapter on drug delivery in the Electronic 'Pulse').

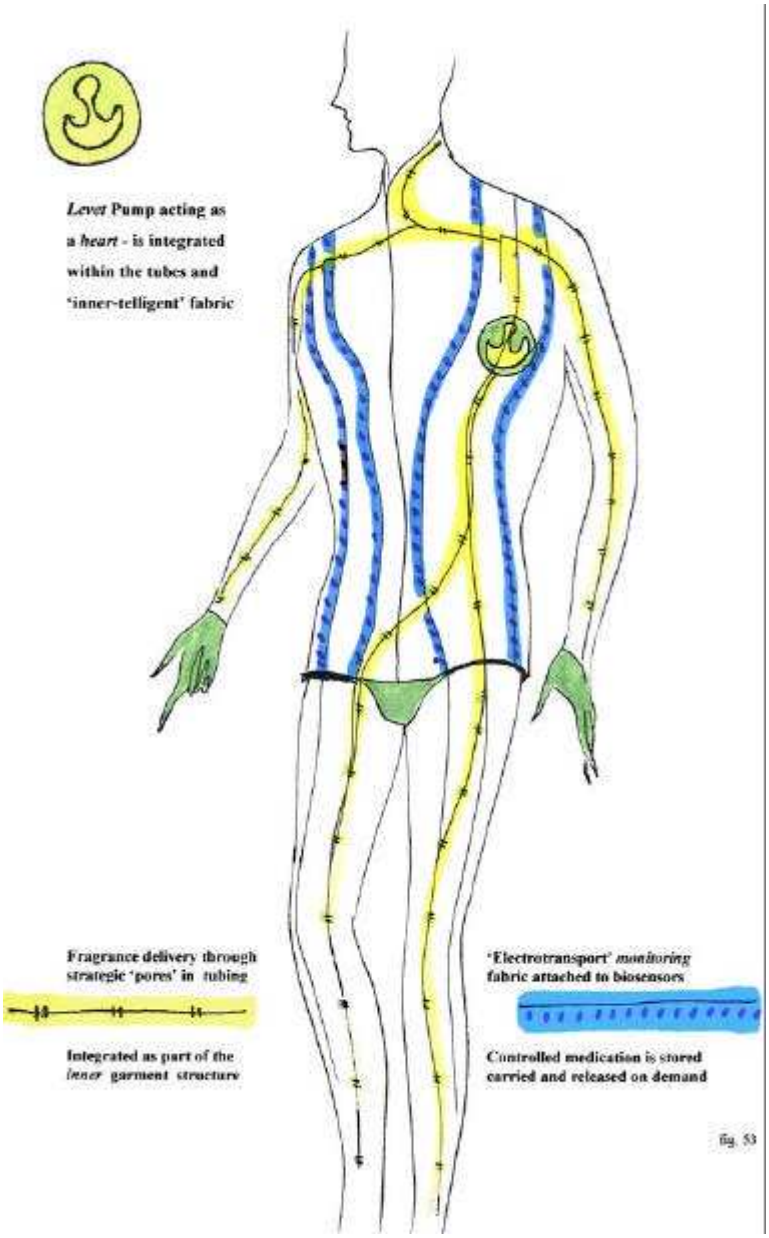
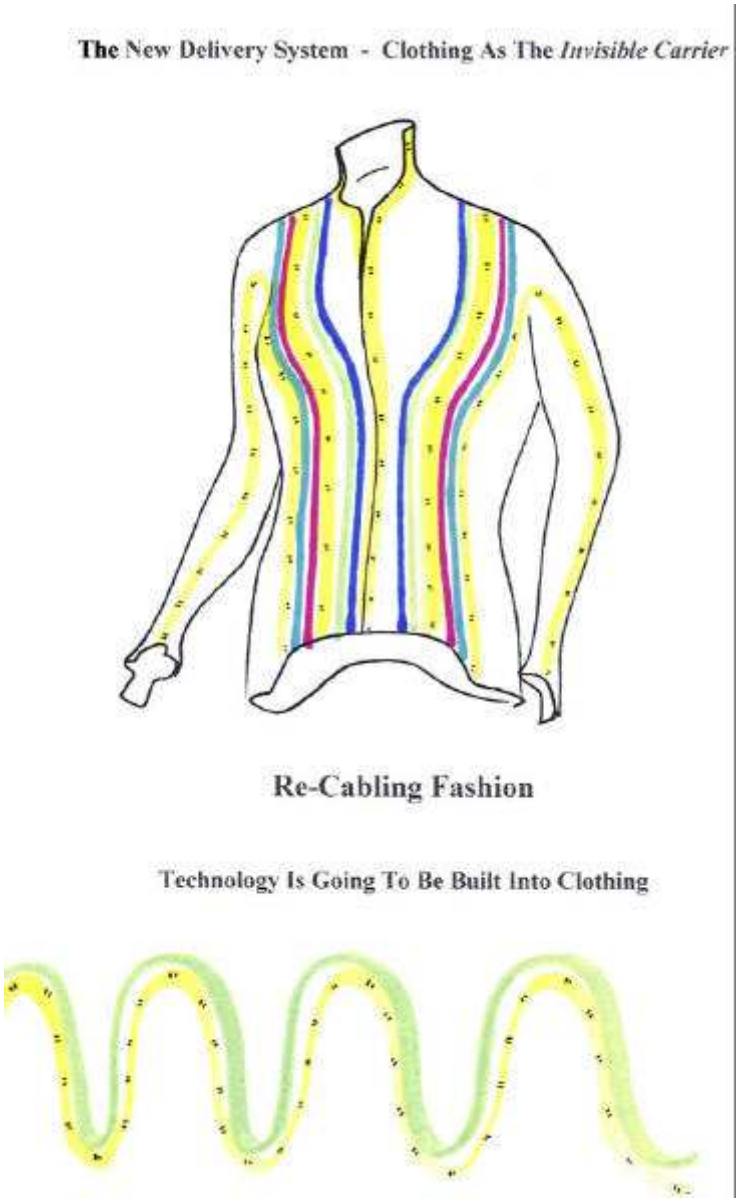


Figure 54 & 55 illustrate further designs for fully fashioned knitted garments.




Fully fashioned 'tube' knitting
fig. 55
Fragrance & medication released at *strategic points* from micro tubes inlayed in garments

Figure 56 shows how miniaturised vaporisers could be integrated into a garment at the collar or cuff, the most prominent and warm areas for applying fragrances.

fig. 56

Figure 57 demonstrates how micro tubing could be part of a fashion design, attached at particular areas of the body within the fabric structure or invisibly embroidered on the surface. As technology dramatically reduces in size, micro tubing and sewing thread (used in the fabrication of garment design) will be the future carrier for a new communication system.

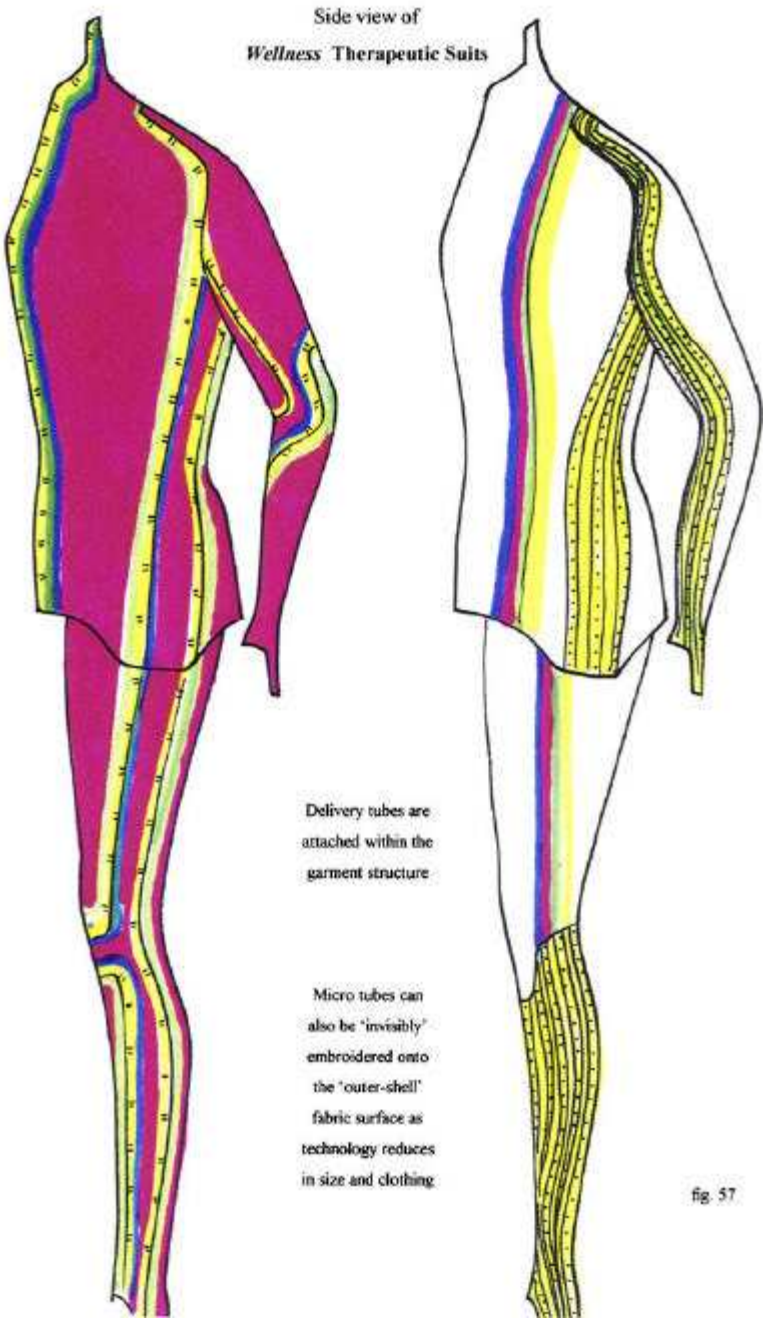
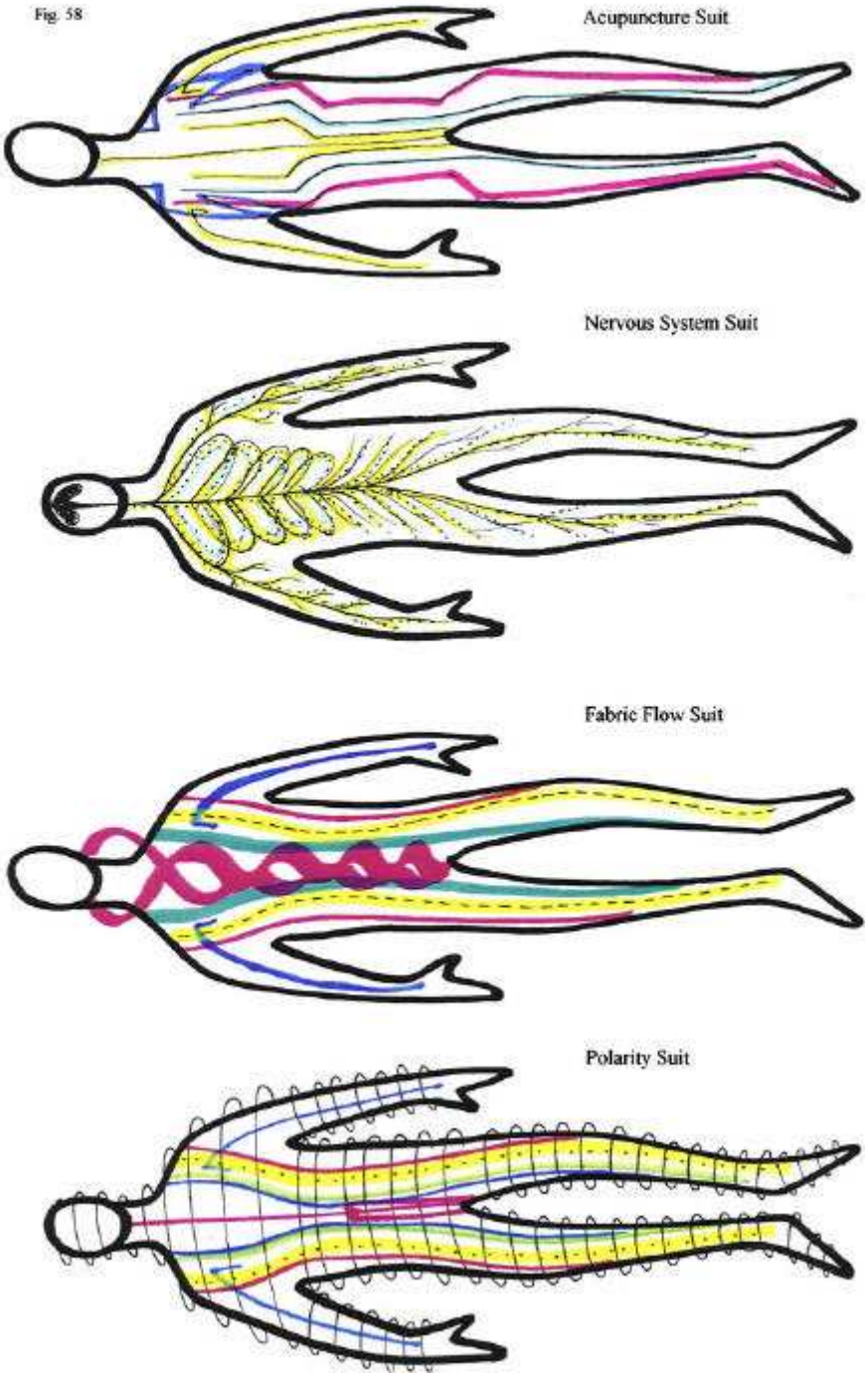
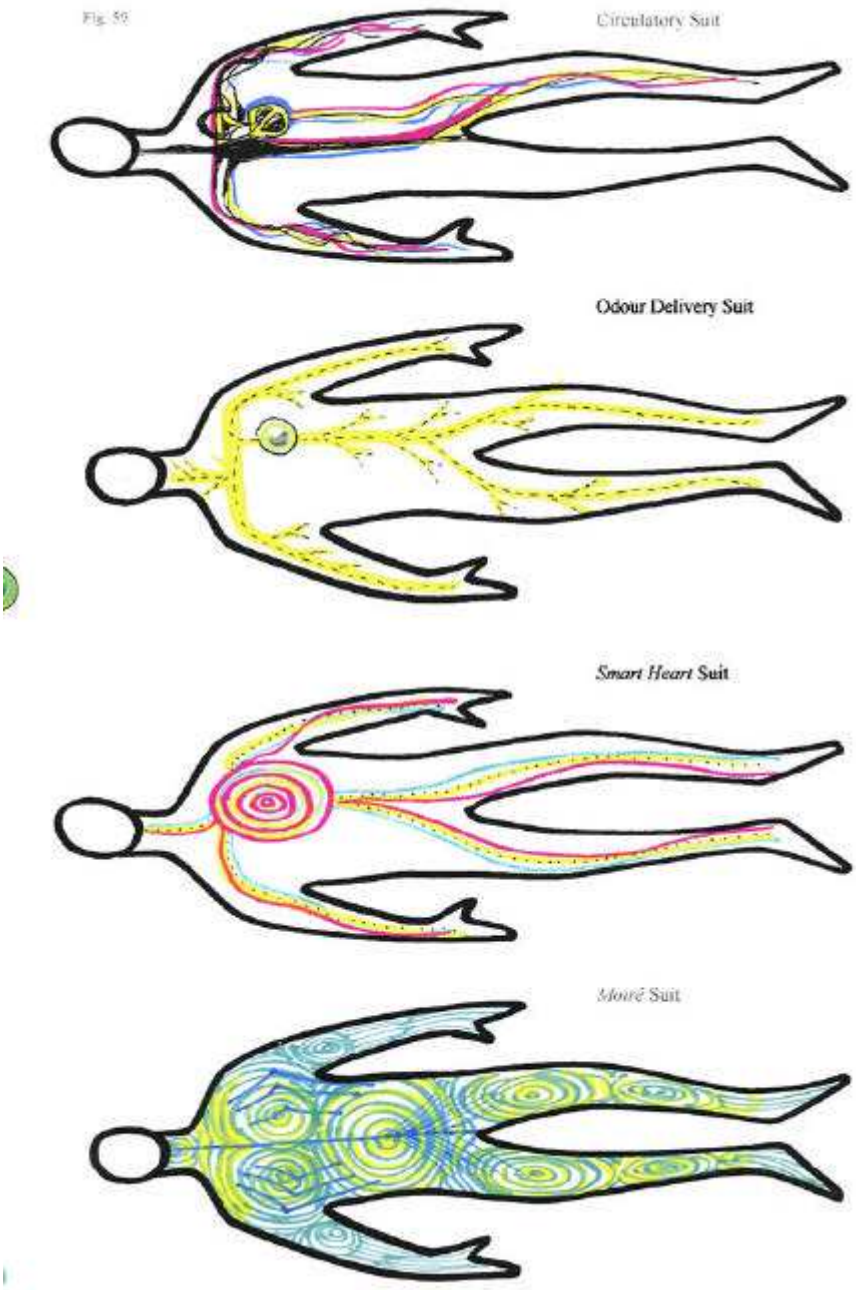


fig. 57

A collection of **'second skin'** dynamic body suits, inspired by the human body and alternative therapies, are illustrated in figures 58 & 59.

Fig. 58





Using a wide variety of textile technologies such as embroidery, bonding, knitting multi-layered cloth, fully fashioned knitting, stitched reinforcements, implanting, weaving double / triple cloth, braiding, 3D weft knitting, tubing can therefore be seen as decorative detailing to garments, or else be disguised within the fabric structure. Possible examples of modern technologies will be discussed in further detail during the following Chapter called *Fabric Files*.

At this stage in the research it is important to stress that where tubing is applied to clothing using various *textile technologies* it is not possible to cut through the centre. Therefore tubes responsible for 'delivery' must be layered or embroidered onto a surface until technology allows it to become the intrinsic aspect of the delicate smart 'delivery' fibre. Fully fashioned knitting or fabric tailored pieces are the solution, as tubing can be carefully inlayed to the correct shape of the pattern piece, preventing any cutting from damaging the 'flow' delivery.

Chapter 10

10 Fabric Files

10.1 Introduction

Fabric Files concentrates on a variety of textile techniques relevant specifically to incorporating a new cabling system of tubing, reservoirs implants, transdermal patches and software intelligence into the membrane structure. The objective is for the fibre and fabric to be compatible with the concept of the 'second skin', emphasising specific properties such as comfort, antiallergenic and touch. Having defined the importance of the interaction process for skin and clothing, it is necessary to review research regarding : - Synthetic Fabrics, Japanese Microfibres, Space Age Technology Fabrics, Fibre Optics, *Science Fiction* Fashion Technology & the *Re-Cabling Mesh*

Textile Technologies : - Embroidery, Bonding, Knitting, Multi-layered cloth, Fully Fashioned 3D Knitting, Stitched reinforcements, Weaving, Braiding and 3D weft knitted fabric dressings.

Due to the broad-based complexity of the project, the following subjects are areas for forward thinking *on completion of the PhD*. These areas concern the evaluation and development and have not been tackled in great depth, such as : - the preservation process, dry cleaning & washing, the *de-clogging* of tube systems with laser drilled holes and the lifespan of a WELLNESS fabric.

Sensorial Fabrics

Questions such as *'Which of the 'senses' can truly distinguish what particular fabric'* are often asked. In May 1996 this research project was invited to give a presentation to various specialists at Courtaulds PLC Research & Development Centre in Coventry and talk about 'touch' (ref 101). As technical engineers of Tencel[1] and Courtelle[2] they were struggling to find technical, descriptive terms for 'touch' with regard to their efforts to engineer their fibres and fabrics to a

[1] A biodegradable 100% cellulose fibre derived from wood pulp
[2] An acrylic fibre

softer or harsher level. This shows the extreme importance of sensory impact on our clothing and how mysteriously we take ‘our senses’ for granted.

10.2 Synthetic Fabrics

Unnatural Ability

Designers and consumers have become re-enchanted with science, technology and what is natural and what might be unnatural in fabrics. Silk, linen and cotton were the status fabrics in the 'technically troubled' 70's and 80's when 'natural' was in fashion. 'Fibre K', more commonly known as *lycra,* has been one of the greatest success fabric stories. The Japanese discovered micro-fibres '*Shin-gosen*',[1] fabrics which are usually nylon or polyester filaments and 60 times finer than a human hair, rivalling all high-touch qualities of natural materials which 'breathe'. During World War II the lack of silk forced the USA to produce nylon. Since then the world market has required more synthetic fibres in order to complement the natural fibres.

Plastic Fantastic

Tencel and polyamide and other *synthetic fibres* are rated highly by modern designers for their 100% unnatural ability (ref. 102). Synthetic is the new height of chic, as designers including Rei Kawakubo, Alexander McQueen, Courreges, Hussein Chalayan, Helmut Lang, Azzedine Alaia, Jean Paul Gaultier, Thierry Mugler and Yohji Yamamoto experiment with the periodic table, creating a foundation for fashion's future. New fabric contents include : - formica, latex, pineapple fibres, polyurethane, cellophane, ripstop, laminated holograms, vinylised cotton, lacquered silk, and resin-coated linen.

Nylon Vinyl

Since 1995 other designers include Calvin Klein, and his nylon suits and rayon-glazed, hammered satin dresses; Anna Sui's vinylized-cotton poplin gangster suits; Dolce & Gabanna's formica raincoats; Donna Karan's olefin-treated paper prom dresses made from FedEX envelopes, Versace and Liza Bruce's latex shirts and vinyl mini's; Prada's white nylon dresses and finally Jil Sander's iridescent silk-lined nylon pantsuits.

[1] Synthetic Japanese fabrics

Japanese "*Shin-gosen"*

In 1993 Dr Okamoto of Toray Industries (ref.103), gave a paper in Finland regarding future pioneering of 'sensual' aspects in textiles. 'S*hin-gosen*' technology is applied to thermochromic and ultra-fine microfibres, making it possible to direct fabrics in almost supernatural directions. Fabrics which feel like peach skin and artificial suede or leather fabrics have the ability and technique to *'azekura"*[1], ensuring good ventilation or preventing rain and light from entering.

From Technology To Culture

Dr Okamoto's presentation concerned trends in textiles, from technology-driven to culture-driven developments. The four current strategies in technical development include : -

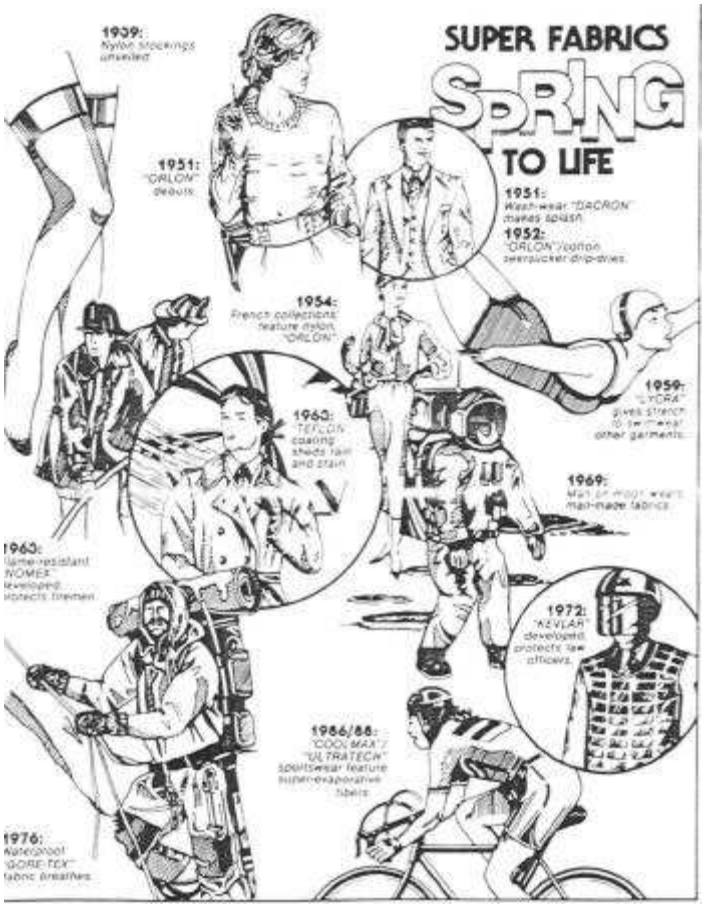
Production Technology	Continuous Polymerization; High-speed spinning; Air-jet loom; Automatic sewing; Computer Dyeing
Industrial Applications	Rope; Fishnet; Non-woven Fabrics; Carbon Fibre; Aramid Fibre
Human Sensibility	Colour Design; Textile & Apparel Design; Shin-Gosen Chameleon Fabrics
New Functions	Hollow Fibre (Artificial kidney) Active Carbon Fibre; Ion-Exchangeable & Ultra-fine Fibre; Wiping Cloth

Space Age Technology Fabrics

For a long while **NASA** have been the pioneers in high-altitude, antiradiation clothing with built-in bioinstrumentation, as described in the chapter relating to *Dynamic Surfaces.* By the time of the Gemini missions, space suits featured a version of stainless steel cloth containing many protective layers. This was culled from the likes of DuPont (ref 104) such as : - uncoated nylon, uncoated nomex, uncoated Dacron, aluminized Dacron, neoprene coated nylon and oxford nylon (fig. 60). The Apollo suit employed 21 super thin layers and replaced the reflective, aluminized silver thermal meteoroid top with nylon white, as early as 1964. The glamorous silver exterior was short-lived, but its influence, in popular memory and fashion, has been far-reaching. The

[1] A technique allowing the fabrics to cool and dry

most recent space shuttle suits, with their own integrated life support systems, are reusable. Velcro found its first use in space, but other fabrics which were regarded as original **NASA** space-age fabrics, for example : mylar, dacron, kapton, nomex, lycra, kevlar and teflon, were commercially available before the designing of space age gear.



10.3 Fibre Technology

Fibre Optics

Fibre optics work on the principle of light travelling and being contained within the fibre due to the outer wall having a different reflective index to the core. Fibre optics can be woven into a garment using a mesh fabric, attached to a light box mechanism, and works by transmitting light outwardly via a multiplicity of polymer fibre optical strands.

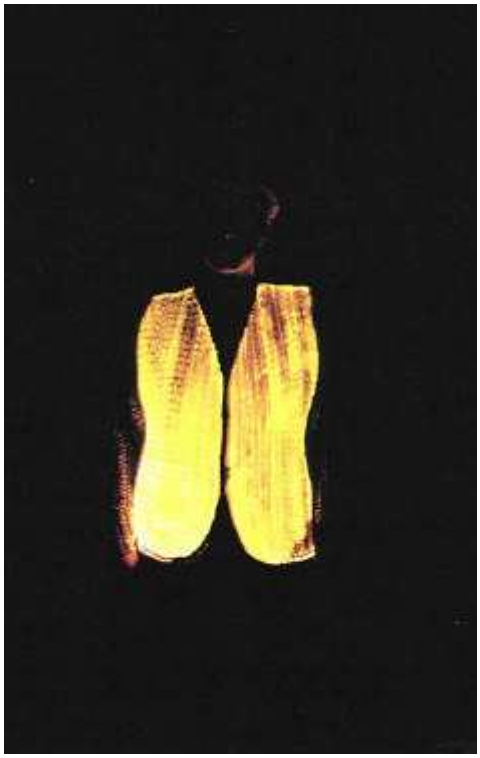
Fibre Communications

By using ultra low loss fibre optic strands, communications between different cities can be achieved. Communication has an extremely high band-width, enabling information to be

transported in a short time, forming a few hundred high band-width information channels ie: colour TV or telephone channels, low bandwidth channels or a mixture of channels.

Safetywear Of The Future

A British invention called *Illumivest* (ref 105 & fig. 61) is setting the pace in developing the next generation of high visibility light emitting fibre materials for safetywear or covering strips. The material is durable, stylish and easy to clean. *Illumivest* is a high-quality vest worn as an over garment for night-time outdoor use, illuminating a person from over 1,500 metres away, giving a continuous 'flashing' appearance and contrasting with conventional safety wear which relies on light falling on its surface to be seen. The wearer remains conspicuous whatever the weather, proving ideal for cyclists, underground workers, horse riders, motor cyclists and pedestrians. Geoff Pinkney [1] of *Illumivest* has previously worked with Designers and Milliners, requiring the technical expertise of weaving optical fibres into a mesh material. However affective and stunning fibre optics appear in garment design, there is always the draw back of carrying a heavy weighted light mechanism and bulky battery connected to the hundreds of fibre strands.



Light Touch

[1] Director of *Illumivest* based in Hemlington, Middlesborough

Sarah Taylor, a lecturer in design at the Scottish College of Textiles, successfully works with light-emitting threads by weaving optical fibres into a textile while it is being manufactured on the loom. (ref 106) Her aim has been to create a versatile woven fabric which is capable of being manipulated into 3D aesthetic forms. She had to learn the physics and characteristics of optical fibres and marry them with her knowledge of 'warp and weft' factors. The tension in the warp threads provides the main structural scaffolding during manufacturing. The weft threads then run horizontally, interlacing with the warp. There are centuries of knowledge about the behaviour of cotton in these processes but nobody before Taylor had investigated how optical fibres might act. Applications include calming blankets for babies born with jaundice. In the medical arena materials hold great possibilities as a stimulant for mentally handicapped people. Changing patterns and colours of light might also calm people down as well as enhancing night club walls.

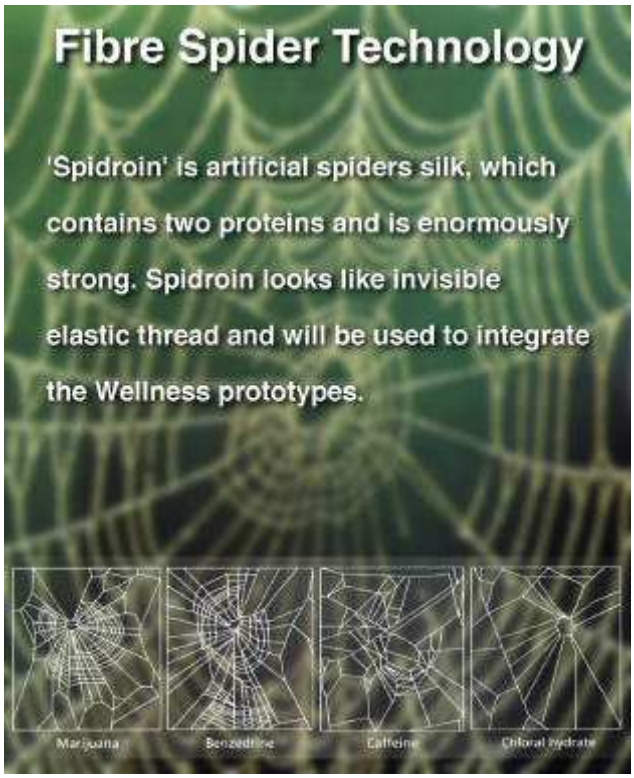
Spider Silk

Researchers at the Department of Molecular Biology, University of Wyoming (ref 107), are solely concentrating on the super-strong *spiders silk*. (fig. 62) This can be used for 3 categories :

1) Reinforcement of fibres in composite materials, parachute cords & catching nets for planes.

2) Biomedical uses for example : - sutures, artificial ligaments, tendon and wound coverings.

2) Consumer products for example : - clothing, climbing ropes and sports equipment.



A Biomaterial For The Future

Spiders silk is made up of two proteins similar to finger nails and feathers. (ref. 108) It is one of the revolutionary new fibres called *Spidroin,* with attractive properties such as invisibility, stretch and elasticity, making it a potential component in high stress areas such as protective clothing. Biotechnologists have found that it could also be used for tendons and non-allergenic sutures. The only major obstacle to the wealth of applications is mass production, because unlike silk worms, spiders are not easy to factory farm. Researchers have now managed to engineer bacteria from spider silk proteins in large quantities in order to make fibres tougher than *Kevlar*, which is the main component for bullet-proof vests.

Absorbent Fibres

Hollow micro fibres swell up and are commonly used in babies nappies, absorbing but not totally 'giving up'. The technology concerning the latest modern superabsorbent fibres will be described in more detail in Chapter 11 on Medical Textiles.

10.4 Textile Technologies

Embroidery

Replaceable embroidery pouches containing reservoirs and components can be embroidered into lining, double faces, piping details, pockets. Tubes can be embroidered or appliquéd onto the surface of the fabric for delivery purposes and as a decorative design.

Embroidery Experiments

Experiments carried out at the Royal College Of Art used invisible nylon thread to sew multi-lumen PTFE tubing onto a selection of fabrics, for example : - neoprene, industrial textile waddings and synthetics. The aim is to prevent perforation to the tubing surface and a 'zig zag' stitch on a domestic Pfaff sewing machine [1] proved to be the most successful for tubes as small as 0.025mm. The Irish Singer machine is more suitable for larger bore tubings.

Embroidered Surgical Implants

Pearsall Sutures of Taunton, (ref. 109) have joined up with the specialist textile research firm Ellis Developments and the Department of Surgery at the Queens Hospital in Nottingham, to develop innovative applications of embroidery techniques to surgical implants. Together they intend to adapt modern industrial embroidery for the manufacture of individual implants.[2] The work is developing a new market with the UK in the lead, involving a computer-controlled embroidery machine constructing textiles to exact dimensions and surgeons specific requirements.

Embroidery at The Media Lab

Towards the beginning of the PhD, in March 1995, the opportunity arose to visit the Media Lab, Massachusetts, to discuss concepts with Professor Michael Hawley and experiment with his fanciful embroidery circuit machine. At that time he was working in the 'softwear' area and had

[1] Number 10 or 16
[2] Shoulder repairs

successfully connected an embroidery machine to a workstation. Having written and built a custom embroidery language and tools to drive computerised sewing peripherals the programme could convert from postscript to stitch format. The machine can therefore be seen as a 254-thread-per-inch multi-colour printer, which outputs to garments instead of photocopy paper. Potentially, the thread can be conductive wire, optical fibre and in the case of this research project - miniaturised multi-lumen tubes for embroidered *re-cabled* surfaces.

Bonding

Although this system has been around since the early days of Courreges in the 1960's, techniques such as *bonding fabrics* will increasingly be applied with the help of computer-aided design for 21st Century clothing. The technique promises to guarantee exact body measurements of the customer, dispensing with the very outdated size system.

Multi-layering Knitted Fabrics

Weft-inserted warp knit is the knitted process for three-dimensional fibre reinforcements. Complex automated machinery is used and multi-axial or three-dimensional warp knits have been produced by Hi-Tech Composites and Kyntex. (ref. 110) The fabrics offer excellent comfortability and draping characteristics with a low through-the-thickness fibre proportions. Courtaulds Advanced Materials presser-foot technology permits versatile preform shaping, while Raschel knitting apparatus allows for structures of up to 18 layers.

Stitched Reinforcements

This method introduces the through-the-thickness fibres to already laid in fabrics, with layers oriented in weft, warp or bias directions. Variations of this process include the multi-axial stitch-through technologies of Choromat & Cie and Kynytex, needle-punching by Aerolor and the Multi-Axial Spanply System produced by Hi-Tech, with techniques ranging from manual stitching to tufting using stitch-bonding machines (ref. 111).

Three-dimensional Braided Reinforcements

Companies such as Courtaulds Advanced Materials, Atlantic Research Corp and the General Electric Company are successful in their capability for direct formation of complicated structural 3-D braided shapes, for the stiffness and damage resistance they allow (ref. 112). The process is slow and expensive, and unlike 3D stitching, weaving and knitting it cannot be adapted from conventional braiding. 3-D fibre reinforcement is nevertheless a growing area with funding from

NASA Langley Research Centre USA for institutions such as the North Carolina State University, using the increasing area of computer-aided design and automated techniques.

Multi-layer Woven Reinforcements

Multi-layered 3-D woven reinforcements are developed at Vorverk in Germany, Techniweave in the USA and the Cambridge Consultants Ltd (ref 113) in collaboration with the Royal Aircraft Establishment. 3-D fabrics on a conventional loom are produced at UMIST and Bath University.

Traditional weaving is one of the oldest technologies known to man. Jonathan Crabtree, a previous researcher at the Royal College Of Art, specialised in woven layers of cloth and multi-layered research methods. His technical expertise led to the invention of a survival 'stretcher'.

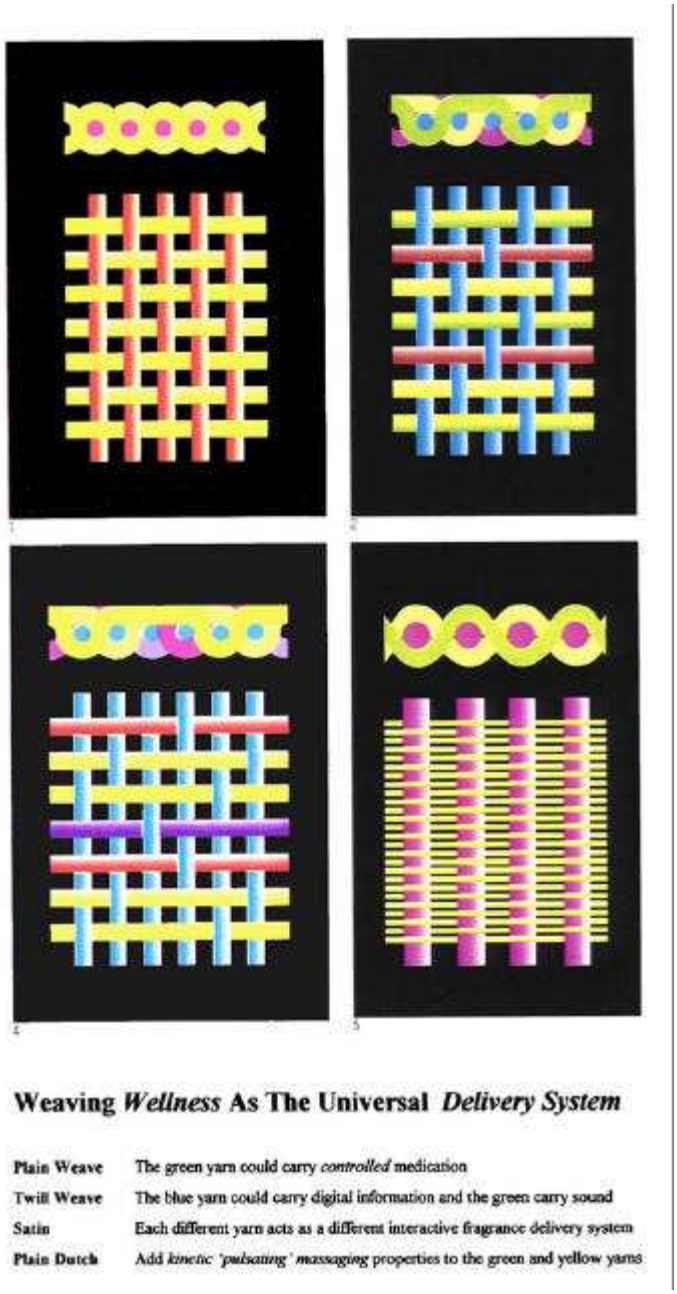
Weaving With Tubes

In January 1996 the research project experimented on a jacquard loom by threading medical tubing through ‘channels’ in a piece of woven double cloth. Random ‘channels’ were designed using computer-aided design equipment acting as the *shell* for the tube and delivery system. Experiments were not particularly successful as tubes were too rigid and needed to be flexible in order to thread successfully through repeated patterns in the fabric. Nevertheless, this method proved capable of containing and protecting micro tubes. More successful experiments were undertaken using the Harris loom and weaving a continuous tube through fabric.

Any Fibre Can Be Woven Into Fabric.

This can be a fibre or an invisible nano tube ‘carrier’ containing digital information or fibre optics. As discussed in Chapter 4 on *Fragrance Delivery*, fibres with 'smart' qualities containing microencapsulated fragrances can already be applied to fabrics. However, the time span is limited as there is no method to ‘re-charge’ or ‘re-fill’ a fragrant fabric which inevitably fades in the wash.

Figure 63 shows an ambitious illustration expressing future applications whereby tubes *could* be woven into fabrics as a ‘carrier’, pumping information or fluids at high pressure. Pulsating therapeutic properties, activated mechanically and electronically, could therefore be woven as the universal delivery system, a step further than transdermal patches and microencapsulation. Tubes would evidently require *micro attachments*, containing nano-sized reservoirs, biosensors and pumps. However, the illustration demonstrates possibilities of weaving “anything” into a fabric.



Fully Fashioned Knitting

Knitted samples were also carried out in March 1996, whereby tubing's (with a diameter as small as 0.5 mm) were inlayed in the ripples on a 10 gauge Daubied machine. Fully fashioned pattern pieces with specific 'tubing', nano-pumping devices and biosensors could therefore be knitted successfully. It also proved possible to completely knit with silicon tubing alone, although this was not as successful as inlaying tubes. The background yarn is essential for necessary strength, which tended to cause problems as yarns occasionally broke. Examples including nylon and *spidroin* are recommended for strength. Knitted 'stretch' is perfect for 'smart' memory qualities,

fibre 'breathing' and kinetic action. Figure 64 demonstrates an example of how a structure with three knitted coloured tubes could deliver fragrances, medication, temperature and sound. In this

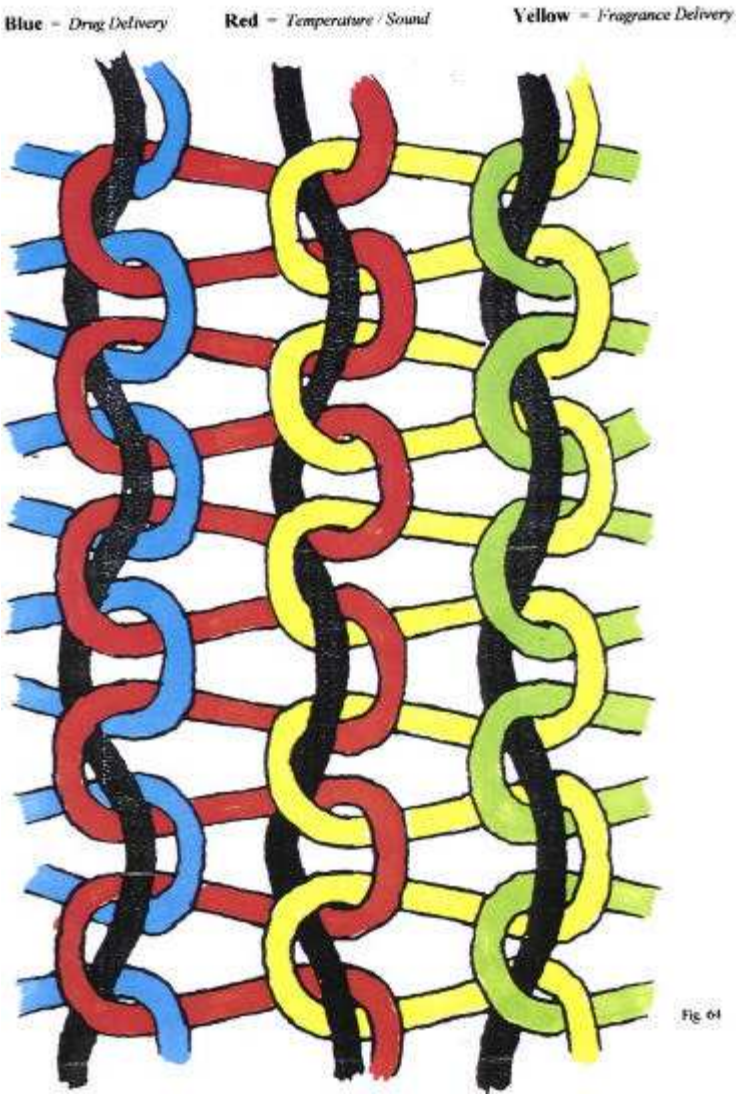


Fig. 64

case the black tube illustrates the centre for sensing, mechanical and electronic components.

3D Weft Knitted Fabric Dressings

David Miller, a senior technical knit researcher and lecturer at De Montford University UK, specialises in 3D fully fashioned techniques (ref 114). New knitting machines can provide a variety of medical dressings, formed with both simple and complex knitting sequences. Elastane yarns are good for stretch, recovery properties, comfort and compression required for post-medical treatment. Manufacturing amputation stump socks is made on hand knitting machines or the latest compact flat knitting CAD equipment. Technology engineers' machines to 'knit a 3D hyper fully-fashioned leg' are suitable products for burns and amputations, by generating 3D

modelling effects. Despite the usefulness of single-knit and 1x1 rib knitted structures the availability of total design CAD systems that prepare data has now enhanced the potential for 3D products. This technology would enable the possibility of knitting an all-in-one therapeutic body suit which could have tubes and micro-machines totally integrated from head to toe. The Smith & Nephew Group for Medical Textiles, who are one of the leading healthcare businesses, are also at the fore-front of three-dimensional knitted structures.

10.5 Preservation Of Future Fabrics

Washing And De-Clogging

"Wear until it smells, then clean with a damp cloth." Could this be the possible 21st century cleaning philosophy for a revolution in textile treatments and simulated fabrics. Is this on the verge of creating a veritable fashion wave? Whatever questions are asked at this stage in the research problems arise with respect to *cleaning* and *de-clogging* micro-bore tubing. Extensive further research is anticipated due to the minute scale of the tubes and the laser drilled holes.

Refill & Recharging

Fragrance and medication will need to be fully protected and re-charged. At this stage in the research it is anticipated that all micro mechanics, fragrance reservoirs and biosensors would be removable in order to survive washing or dry cleaning. Nevertheless, tubes would remain in the structure, as the inner bone structure. A suitable package could also protect the chips and power source for example : - a rechargeable battery by a generator powered by body movement of self winding watches, or by light. Consequently, the answer is to recharge the fragrance delivery areas with perfume after the garment has been washed. This will be necessary since the initial dose of fragrance will not last forever. The notes in a fragrance change with time as the more volatile components become depleted. This could be overcome by having different release areas for each component and matching the dose quantity and/or release rate to give a consistent aroma over time, with the option to vary the blend at will.

Wellness Fabric Lifespan

The key disadvantages with all electronic delivery systems is cost, portability and battery life. The delivery of fragrance and medication requires absolute reliability and the comparatively slow turnover rates of medicinal products requires a long shelf life. These battery requirements always

cost, although re-useable systems with rechargeable batteries will improve the situation. However re-usable systems can raise hygiene issues and the number or re-use needs to be controlled to minimise the risk of component failure.

10.6 Conclusion

As technology reduces in size, batteries, biosensors and all micro-mechanics discussed in this research project will become increasingly more portable, disguisable, flexible and easy to implant into multi-layered fabrics. The sewing thread will become the 'delivery' carrying system and tubes will be fully disguised in the piping and seams of garments and pockets (fig. 53). Vaporisers will be disguised as the intrinsic part of jewellery, accessories, zippers, buttons, collars and cufflinks (fig. 56) - and it is at this point that the research moves on from fashion fabrics to the next second skin - from fabric to artificial skin - and from artificial skin to the future *medical fashion fabric.*

Chapter 11

11 Medical Textiles

11.1 Introduction

In the beginning, nature provided for our protection the most scientifically advanced fabric ever created . . . . . Our skin.

The Second Skin

Skin is the largest organ in the human body. This chapter will discuss the earlier and most recent developments, relating to Drug Delivery and Medical Fabrics. Human skin is heavily targeted by pharmaceutical companies who are always looking for something which is novel. Medical textiles look at the *next second skin* and the *artificial skin*. Skin-fabrics offer the flexibility to work with the elements and yet provide perfect control, with the strength to withstand extremes of temperature, exposure to ultra-violet light and complex chemicals

Dynamic Delivery

As described in Chapter 8 on the Electronic 'Pulse', drug delivery encompasses vastly expensive technologies designed to enhance the delivery of drugs into human bodies. It is an ancient pursuit, originating back to 1500BC when the first gaggles, ointments, inhalations and suppositories were documented. Nowadays these technologies have evolved through transdermal, oral, topical, respiratory, vaginal, parental, ocular, transmucosal, rectal, nasal and aural routes (ref. 115). Drug delivery is a highly dynamic industry, working in parallel with the pharmaceutical industries.

Medical Textiles Conference

Having documented a variety of research collated over the past two years and whilst visiting the Bolton Institute Medical Textiles Conference, in July 1996, we can see the vital and innovative field of Medical Textiles. The increasingly developing area of incorporated *'drug delivery'* applications have already advanced the experience of life - and will do so more.

Medical Textiles

Fabrics will be used to extend the boundaries of physical endurance and create the optimum moist healing environment. The rigours of the modern world and the physical challenges which face individuals today demand a level of protection and performance which even nature has not provided for. The main market is for medical cottons such as wound dressings, as the growing relevance of environmental awareness for cotton processors and improved understanding of the role of bleached cotton in allergies have prompted much interest in hydrogen peroxide bleaching.

11.2 Development Of Biotextiles

Biologically Bonded

A *biotextile* [1] is a biologically active material, usually a complex composition having a biologically active agent incorporated into its structure and bonded by several different types of chemical or physical links (ref. 116). When in contact with moisture (air, blood, skin, water) it is activated and the biologically active compound starts to be released from the fibrous material to the desired area of the body. This serves as a *store* for drugs and the rate and duration will be controlled. The release system can occur over long periods of time, causing lower toxicity compared with standard methods of drug delivery.

The Biotextile can be classified according to the drugs incorporated in the textile surface, ie :

Antimicrobial Textiles

Reduction of microbe fungi and virus contamination via bioactive textiles has proved to be the most effective, as they can be made up into reusable garments in submarines (reducing bacteria in the air), operating rooms (medical staff and patients), bed linen, carpets and curtains. Combining *antibiotics* with antibacterial agents in wound and burn care for military surgery is currently being researched, although very little published information is available.

Bussey-Hewitt Processing Ltd UK's antibacterial wools assist in skin healing and regeneration, absorbing and vaporising perspiration more readily than untreated wool.

[1] Fibrous drug delivery system integrated in a textile

Anaesthetic Textiles

Fibrous materials over other polymeric materials are proving advantageous for creating a specific depot for long-lasting action drugs and pain relievers. The first investigation was in 1970, in Leningrad, whereby topical anaesthetics such as Novocaine were incorporated into modified PVA[1] fibres. The results were 50-100% longer than that of cotton swab control samples. In 1973 a cellulose material with 5-15% bonded topical anaesthetic was tested as a wound dressing with a duration of 4 to 72 hours, depending on the wound.

Anticancer Textiles

Implantable drug delivery systems for chemotherapy of tumours allow the controlled release and direct distribution of chemotherapeutic agents to desired body organs. Millions of dollars world-wide are spent, trying to solve problems because of the desperate success in the development of reliable anticancer delivery systems. Russian development with anticancer agents into PVC fibrous materials began in the early 1970's, but it was not until the early 1990's that the USA caught onto the idea. Dr Henry Brem at the Johns Hopkins University developed a controlled release polymer system for delivery to the brain, proving the effectiveness for brain tumours incurable by traditional methods.

X-ray Active Textiles

Other textiles were developed for the treatment of skin diseases and tumours as an alternative to x-ray therapy, involving high doses of radiation, consequently producing burns. Russian Researchers in 1967 developed isotopes delivered through cellulose textiles with beta radiation but the isotope distribution did not produce uniform levels of radiation on the skin. Later experiments incorporated covalently bonded isotopes into man-made fibres ie: PVA, polyamide and rayon, remaining active after treatment in hot water, organic solvents and diluted acids. They were tested as X-ray active soft implants and immunodepressants, recommended as topical immunodepressant for transplantation and implantation surgery.

Other fibrous materials include **Enzymatic, Haemostatic & Haemodilutive Textiles** as well as **Multifunctional Fibrous Drug Delivery Systems** (ref. 117). Combining drugs into *one fibre* can give unique qualities which cannot be achieved using traditional drug delivery technologies.

[1] Polyvinyl alcohol

This is a very new area and the potential applications could open up revolutionary applications for textile and fibre industries, competing with pharmaceutical industries.

11.3 Transdermal Drug Delivery

Transdermal Therapeutic System Technology (TTST) by **ALZA** Corporation, USA (ref. 118) allows drug delivery through intact skin rather than through invasive methods such as injections.[1] They consist of a thin flexible composite of membranes which can include an impermeable backing, a solid or liquid reservoir containing the drug, an adhesive and a rate-controlling membrane (see figure 34 on page 85). After the system is applied the drug permeates through the skin and into the bloodstream at a rate regulated and pre-programmed by the membrane (maximising therapeutic effects and minimising side effects). Skin permeability varies significantly from person to person so therefore it is desirable to have some degree of system control to ensure the pre-programmed delivery rate. They can be worn whilst washing and swimming and are designed to allow continuous wearing. Regarding skin irritation and sensitisation problems, influential factors include duration of therapy, duration of individual patch application, the adhesives used and the rate of delivery, all factors which are taken into account during the development.

Transdermal **ALZA** Products On The Market Or Under Development : -

Nicoderm delivers nicotine for 24 hours for smokers as an aid for nicotine withdrawal.
Duragesic provides 72 hours of pain control for cancer patients requiring opioid analgesia.
Catapres-TSS delivers clonidine for 7 days treating high blood pressure.
Transdermal-Nitro prevents & treats angina pectoris pain from coronary artery disease.
Estraderm administers the body's natural form of oestrogen for postmenopausal symptoms.
Transderm Scop provides effective protection from motion sickness for up to 3 days.
Testerderm delivers the male hormone testosterone for men with a deficiency illustrate.

ELAN Corporation PLC are also pioneers and specialists in transdermal delivery and especially iontophoresis pre-programmed technologies.

[1] Similar to administering a closely monitored I.V.infusion without a needle

Some of the well documented benefits of transdermal delivery include : -

(i) Elimination of variables influencing absorption from gastrointestinal tract: - pH & food intake.

(ii) Reductions in the frequency of dosing (especially drugs of poor bioavailability).

(iii) Elimination of the first pass effects of the liver.

(iv) The potential for smooth plasma profiles devoid of peaks and troughs.

Nicotine Release

ELAN'S initial transdermal research concentrated on matrix reservoir systems, investigating transdermal delivery with and without rate controlling membranes, leading to the international success of transdermal nicotine patches. The product is called *Dermaflex,* consisting of a reservoir containing a hydrogel matrix where the drug is evenly distributed through the layers of skin to the systemic circulation (ref. 119). There is no rate controlling membrane for regulating the nicotine release- hence drug loading and residue within the reservoir are minimised, leading to enhanced safety and economy. Further developments in nicotine patches use water based adhesives and are convenient due to their small size, inherent flexibility and ease of manufacture. This elegant flexible film patch can be used for a number of candidate drugs.

Iontophoretic Devices

Panoderm is a lightweight adhesive patch which is a disposable and reusable iontophoretic device with a microprocessor control unit applied to many parts of the body. The underside contains two gel reservoirs directly in contact with the skin. Both gels contain electrodes, although one holds the drugs. Once the device is activated the current is generated from the internal battery, passing from one electrode to the other, charging the drug as a carrier of charge. This drug in attempting to reach the other electrode must transverse the skin which is swept into the general circulation via the underlying capillary network. When the current stops, so does the delivery of the drug.

11.4 Recent Developments In Medical Textiles 1995-1997

Superabsorbent Fibres

Technical Absorbents Ltd [1] have created a fibre called "*Oasis"* (ref. 120). This is heavily claimed to be the key to the next generation of medical products, offering fluid absorbency properties associated with superabsorbent powders but with additional characteristics due to their structure. They are cardable, can be blended with other fibres, and have no sharp puncturing particles. The rate of blood absorbency is dramatically higher as the degree of *'swelling'* and the ability to retain fluids rapidly, or under pressure, is far more efficient than superabsorbent powders. The fibre is 95% water when swollen and 5% fibre and although they can be dried for reusability they are non washable as water will break the 'gel'. The fibres are also used in optical fibres to absorb unwanted water and can be bonded thermally or with latex in non-wovens. In Japan wound dressings wipes contain up to 30% superabsorbent fibres such as '*Oasis*' and are produced with ostomy products.

Similar to '*Oasis*', a Canadian-US firm Camelot are developing "*Fiberdri"*, with a simpler and slimmer construction, although neither of these two products are commercially available yet.

Kinetics of Penetration of Insects

At the Technical University Liberec in the Czech Republic (ref. 121) the kinetics of penetration of mites through a textile layer were assessed by establishing an antiallergic medical textile barrier to household mites. The textile pore size relative to the mite dimension was a prime factor, with the pore size being affected by repeated laundering. The results were based on the distribution of these two elements making no differentiation between a mite and its excrement, and withstood the influence of humidity within the bed.

Finely Woven

'Microguard' by Teijin Ltd of Japan (ref. 122), is a comforting fabric from a new micro-fibre with an *extremely tight weave.* It offers no space for mites, their dead bodies, excrement or dust to pass through. The micro-fibre has the fineness of one-fifth of silk and is beneficial for bronchial asthmatics, atopic dermatitis, children, sensitive skin and is successfully used to cover bed-linen, soft toys, cushions and quilts. It is particularly beneficial where it is warm and there is

[1] In conjunction with Courthaulds PLC Fibres, Coventry UK

central heating. Teijin Ltd claim that there are no harmful chemicals and washing does not reduce its effectiveness or softness.

Multi-layered 'Lycra'

A new 'body suit' development has been created by the UK company *John Copley - Camp Orthotic Services Ltd* (ref. 123). Originally conceived as a burns garment, it is now manufactured as an aid in the motor control and posture of cerebral palsy sufferers. The posture support to remain upright has interested both physiotherapists and Consultants, requiring further research into how the garment mysteriously works to improve control for patients.

'Cool X' Cooling Gels

An estimated 5000 people sprain their ankles everyday. Robinson Healthcare (ref. 124), a leading UK medical manufacturer, have launched an adhesive plaster containing cooling agents for immediate pain relief and long-lasting ice-cold action. The gel is contained in a soft non-woven material, moulded to the body for up to 6 hours with no need for freezer storage.

Tissue-Engineered Skin Replacement

'Dermagraft' by Smith & Nephew UK (ref. 125) is the first developed tissue-engineered skin replacement product. Available towards the end of 1997, this is the result of Smith & Nephew and an American company called Advanced Tissue Sciences. It has involved the successful development of tissue-engineered cartilage for orthopaedic applications. The technology is similar to that used for replacing cartilage, with tissue-engineered dermis[1] being created by culturing human cells on a biodegradable mesh in a nutrient-rich environment. The cells grow on the mesh as they would in the human body and lay down 'new tissue'. *Dermagraft* will be used for the treatment of chronic foot ulcers, which is the unpleasant cause of 55,000 amputations in the USA each year.

Acne & Athletes Foot Treatment

A sulphur-containing antibacterial fibre, called '*Security'*, developed by Asahi Chemical Industry Company (ref. 126), claims to eliminate the bacteria responsible for acne, athlete's foot and the odour producing staphylococcus when used for sock manufacture. The fibre will be produced and converted into face masks and bandages.

[1] The inner skin

Antimicrobial Panelled Underwear

R.Braunstein from North Carolina, USA (ref. 127), have designed a knitted 'crotch' for women's underwear containing yarns treated with an antimicrobial agent. This claims to kill bacterial yeasts without harming the wearer, by using open knit structures and treated acetated yarns. Finally this is *laid-in or knitted-in* with untreated yarns of polyester or polypropylene.

11.5 *Nature* Inspired Medical Textiles

Alginate & Novel Polysaccharide Fibres

Innovative Technologies Ltd (UK) (ref. 128) have been experimenting with natural polysaccharides, such as the incredibly strong *chitin* [1] *chitosan, alginate*[2], *pectin*[3] , and *cellulose.* These have a number of unique properties that are ideal for Medical Textiles when processed into yarns. They do not dry out and stick to the wound, accelerating the healing process. The biopolymers are often biocompatible, biodegradable and highly hydrophilic. 'Intelligent' films and fibres are engineered on a molecular level to achieve the gelling properties and the high absorbency of the wound dressings.

Delivery By *Seaweed*

Alginate is widely used as an excellent wound dressing. Bolton Institute and ConvaTec (UK) are developing an alginate fibre form drug delivery system, (ref. 129) based on sodium alginate and its derivatives. The mechanism of ion exchange of sodium alginate and loaded drugs has been investigated. 'Silver' containing *antibiotics*, can be successfully incorporated into alginate fibres using normal spinning techniques.

Chicken Feather Fibres

A new white absorbent fibre called *PPPF*, developed by the US Department of Agriculture, Environmental Chemistry, Beltsville in Maryland, (ref. 130), grind unwanted chicken farm feathers into hollow fibres. The lumen can be loaded with therapeutic agents and surfaces can be similarly coated, since the production process removes soluble proteins from the keratin surface. They are expected to compete with wood pulp in disposable nappies, hospital wipes, femine hygiene products and eventually filtration, speciality papers and structural composites. It is believed they are more absorbent than existing man-made fibres with interesting wicking

[1] Found in the shells and skins of insects, crabs, lobsters, shrimps and mushrooms
[2] Seaweed

properties, enabling moisture and blood to be distributed more evenly with beneficial wet collapse resistance and greater bulk density. They are also less expensive.

Soothing Healthcare Fibres

'Stayers', by the Japanese company Fuji Spinning Co Ltd (ref. 131) offer a soothing material which activates the body's natural healing properties and immune system, using 18 naturally existing and carefully selected rare minerals [1] 'crushed' into microparticles[2]. The minerals are harmless, occurring naturally in hot springs, giving the fibres their therapeutic function. Fuji, moreover, stress that their radioactivity satisfies the standards of International Commission on Radiological Control. *Stayers* release natural radioactive rare gases and *thoron*,[3] generating minute ions by ionization. The 'minus ion wave' creates a soothing relaxed feeling and stimulation of metabolism. The deodorizing, sterilizing and 'hormesis' effect has low level radiant rays and benefits the human body by activating the immune system.

Collagen Wound Dressings

Developing processes at Collatech Pharm Ltd Israel (ref. 132) are underway for the efficient extraction of natural collagen, including several innovation commercial applications for collagen in medicine. Collagen biological wound dressings will be on sale by 1999, used as a replacement for grafting over large burns, because they protect damaged tissue, accelerating the healing process. Collagen bone implants can substitute metal strips in bone repair, offering the considerable advantage that they stimulate bone formation and dissolve so that there is no need to remove them.

Fungal Filaments

Materials based on fungal filaments literally *'grow'* (ref. 133). A non-woven fabric grown from micro-hypae has excellent thermal insulation properties and can be achieved with tubular and hollow formations. Products made from fungi accelerate wound healing, therefore making the filaments ideal for medical use. Hyphae contains *Chitin* and *Chitosan*, promoting growth of fibroblasts and releasing minute quantities of hydrogen peroxide, which is sufficient to stimulate white blood cells and skin growth. Due to the brittle nature of the filaments, micro-fungal cannot be spun, but fabricated, either wetlaid, or mixed with conventional textile fibres.

[3] Citrus Peel
[1] Including Uranium, thorium, cerium and neodymium
[2] 0.7 nanometres in size
[3] Released in extremely high concentrations in hot springs, for medical treatments

11.6 Conclusion

2001

A market research report by Frost & Sullivan in California (ref 134) carried out in 1995 claimed that the combined markets for artificial organs and replacement skin alone - virtually non-existent today - will exceed $2 billion by the year 2001. As technology moves increasingly towards biological products companies will gain market niches for life-threatening indications yet to be addressed. The late 1990's will see dramatic increases in the number of organ transplants and introductions of innovative new products.

Delivering Statistics

In 1996 the world wide pharmaceutical market was worth US$195 billion, with drugs incorporating drug delivery systems (including Medical Textiles) worth US$13.8 billion. By the year 2000 these figures are expected to increase to US$250 billion and US$50.2 respectively.

In 1994 the leading top 40 prescription drugs, by world-wide sales, contained three biotechnology derived drugs. With on going advances in molecular biology and gene therapy the biotechnology industry is set to explode in the coming years. Each new molecule (however effective as a therapeutic agent) will be subjected to the same limiting factors in drug delivery and whoever can devise the most effective, user friendly method of administrating these molecules - will make a significant impact on pharmaceutical products and Medical Textiles.

Concluding with these statistics it is inevitable to predict that future applications in medical textiles and biotechnology will develop into every day clothing and not just wound dressings. Fashion garments will carry health and safety labels such as ‘well-being’ or ‘wellness’. Controlled drug delivery will be safely worn in undergarments or other garments, as clothing becomes the therapeutic super *invisible technology*. Consequently, we will wear our health system. As more money is spent in the international pharmaceutical industries, the need for high technology and an advanced non-invasive delivery system dramatically increases. More quantities of drugs will *urgently* be needed for the ever increasing older population (discussed in the forthcoming chapter) and fabric for clothing proves to be an ideal vehicle for future delivery.

Chapter 12

12 2020 50/50

12.1 Introduction

*'In the year **2020, 50**% of the European population will be over **50** and most people can expect to live until 80 - or beyond.'* (ref. 135)

This particular chapter is dedicated to the elderly and what designers are looking for in order to improve the life-style of the elderly generation. It is also important to high-light 'olfaction' in the elderly, which is so often easily ignored.

12.2 Improving Life For The Elderly

The baby boom of the fifties and sixties insists on the 'granny boom' by the year 2020. Old people are, however, having a rough deal as less money is allocated to care-work. While many see improved life expectancy as a triumph of social development and public health, WHO[1] suggests that this is bringing a major crisis to parts of the world. Even in richer countries longevity can sometimes seem more of a punishment than a blessing. In the year 2020 Universal Governments will be dealing with chronic problems relating to elderly over-crowding and diseases.

As humans living longer years we can expect to live 30 further years after full time working, during which we will continue to play an active and fulfilling role in society or find ourselves ignored and patronised. An estimated 165 million people world-wide - most of them elderly - have rheumatoid arthritis (ref. 136). A third of women over 50 have osteoporosis, with an increased risk of bone fractures and the majority of the worlds elderly population suffer from chronic diseases such as stroke, dementia and cancer.

[1] World Health Report 1995

12.3 The Third Age

Designing for the elderly will help take the fear out of their lives, enhance comfort and personal image and reduce unnecessary risks. Throughout the research project close links have been maintained at User Forums[1] with members of the *University of The Third Age,* students and researchers in the *DesignAge* unit at the RCA. Subsequently, the communication - in particularly with members of the Third Age University - has projected the research towards concepts relating to ***friendly fabrics*** **and** ***matey materials***. Whilst outlining the project with members it was unanimously decided that the most resourceful therapeutic properties in futuristic clothing required for the elderly population are : -

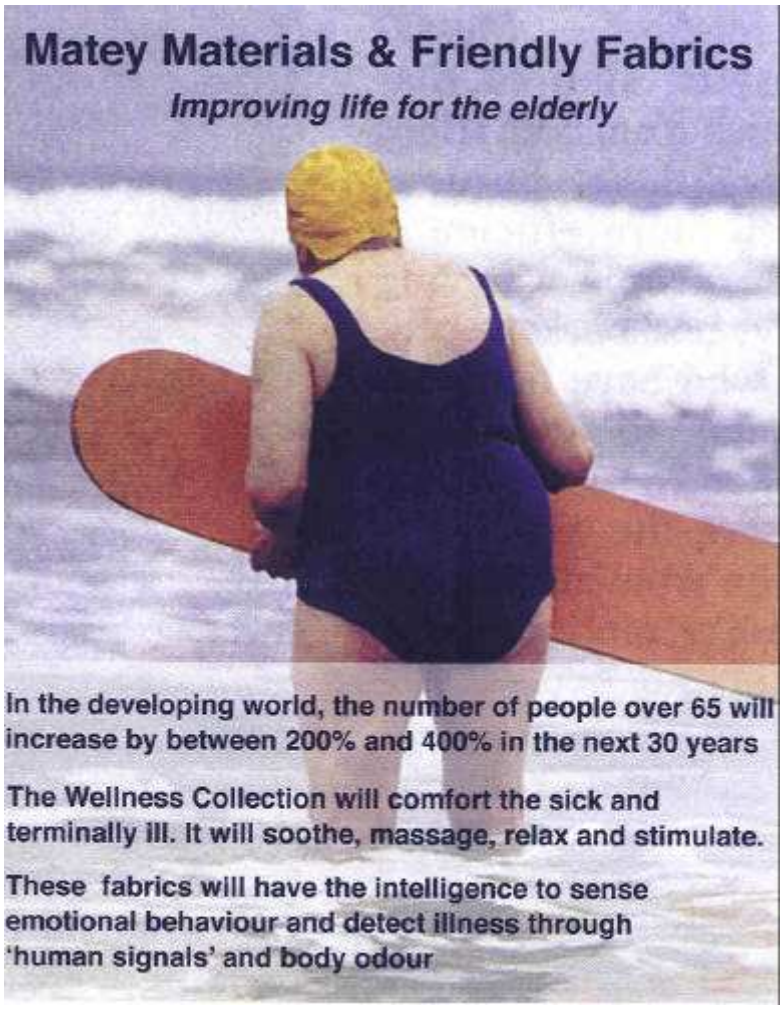
i) *'Instant heat'* which is easily applicable for arthritis and rheumatism.
Surfaces which interact with the skin controlling temperature control.

ii) Beautiful fabrics and clothing with a pleasant odour, enhancing self-confidence.

12.4 My 'Mate' Material

Matey Materials & Friendly Fabrics (The Wellness Collection) speak for themselves (fig.65). They are simply 'data', non-invasive therapeutical fabrics. Research in this field is already underway at the Media Lab "Things That Think" consortium, whereby a patients condition is continually observed, reading *Human Emotional & Biological Behaviour.* The prime importance for 'matey' fabrics concerns the data which detects and documents biomedical information received in human body odour and sweat using Wellness technology. Consequently, it will then monitor and alert. In the near future controlled drug delivery will be *far more* accessibly monitored. There will be no need for intimidating morphine pumps at the hospital. No more ugly pump and wire systems to trip up on.

[1] A Forum where researchers can discuss ideas for the RCA *DesignAge* annual competition



In the past, having worked as a care assistant for the elderly and volunteering for those affected by HIV & AIDS, experience proves the sheer necessity for advanced bioscientific materials. ‘Smart’ medical fabrics will be designed for future bed covers and linen, chairs, mobility cars, hospital gowns, nightwear and wheel chairs. These fabrics are in *'living',* constant dialogue with their environment ie: the hospital ward/theatre and a patients body contact with 'matey, friendly' fabrics

12.5 Losing Olfaction

As we grew older we are more likely to lose our sense of smell. This explains why grandmothers have a tendency to saturate themselves with strong floral odours and over flavour foods. An odour blindness condition known as 'specific anosmia' occurs when a person bangs their head,

suffers from depression or loses their memory. Some people continually forget to fuel their bodies by eating, as they have no sense or enjoyment of smell.

Smell Therapy can do nothing to stop the diseases such as Alzheimer's but scents can be a real benefit to the elderly, with therapeutic possibilities of the smell-memory-link being explored (ref.137). Fred Dale's[1] "Reminiscence Pack" contains bottles with scents from the past, such as World War I Christmas cake, *wash day* and soot. These have been tested at Clifton Hospital's Rehabilitation Unit in Blackpool, (ref. 138) with seven elderly patients (most of whom had difficulty remembering things a few hours prior to the test) being asked to sniff reminiscing bottles. The results proved that one 76 year old remembered exactly what was on the mantle-piece in her childhood home and a woman of 88 recalled her wartime Co-op dividend number.

12.6 Olfactory Diagnosis In Medicine

'Smelling Sick'

In the days long before medical device technology doctors only relied on their 'senses' and in particular their nose to diagnose a patient. The first case of severe diabetes was recorded in 1798, by the ' *decaying odour of apples'*. Characteristic patient odours accompany many diseases and intoxifications and their recognition can provide diagnostic clues, guide the laboratory evaluation and effect the choice of immediate therapy. In illnesses, acetone is an indicator for diabetic, H2 for dieting and lactose malabsorbtion in renal problems/failures show an 'acid' smell.

Other examples include (ref. 139) : -

DISEASE	ODOUR
Diabetes	sweet or decaying apples
Typhoid	baking bread
German measles	plucked feathers
Scrofula	stale beer
Yellow fever	a butchers shop
Small pox	perspiring geese
Stomach cancer	breath odour fermentation

[1] Smell specialist who makes odours for museums, including the Jorvik Viking Centre in York, UK

Pseudomanas bacteria	musty odour of a wine cellar
Starvation	sweet odour
Swallowing rodenticide	peanuts
Turpentine in urine	violets
Arsenic poisoning	garlic

12.7 Conclusion

Applications for *Matey Materials and Friendly Fabrics* for THE WELLNESS COLLECTION are currently being submitted as an entry for the DesignAge 1997 competition from the RCA School of Fashion & Textiles. These will be exhibited at the RCA Part II graduating show 1997 and will include the multi-coloured 'body suit', illustrated in figure 43 and described in Chapter 8 on the Electronic 'Pulse'. The 'Wellness Therapeutic Suit' demonstrates an *interactive platform* for delivering fragrance and medication and has endless implications for the elderly generation, in a world where more drugs will be circulated and clothing becomes the *invisible technology*. A film[1], called **The Wellness Collection** - *A Science Fashion Story*, supports the practical demonstration of the 'Wellness Therapeutic Suit' and all important aspects of this research project. In particular this emphasises the *active, reactive* second skin, the social context for our older generation and the subject of ***Nanotechnology*** which is explained in the following chapter.

[1] 11 minute documentary and animation by Joanna Woodward and Jenny Tillotson

Chapter 13

13 Nanotechnology

13.1 Introduction

"Technology Is The Future Of Fashion"

Donna Karen - Fashion Designer 1994 (Ref. 140)

Science Fiction May Well Become Science Fashion

Science Fiction authors have imagined many things, some possible, others inflated contradiction of known natural law. Some dreamed of spaceflight, others dreamed of robots- and they came, some dreamed of cheap spaceflight and intelligent machines, and these too are coming.

Smell Is Nanotechnology

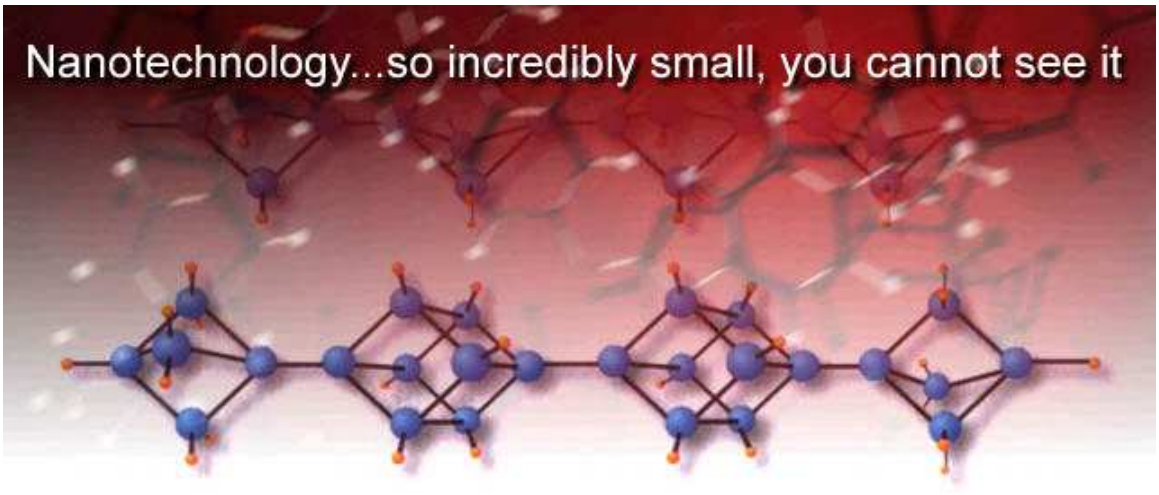
This chapter will touch on the subject of 'Nanotechnology,' which is a serious new science producing systems nature cannot supply. It literally borrows techniques from biology. For this reason, it is safe to say that SMELL *IS* NANOTECHNOLOGY because of tiny molecules involved in its structure. *Nanotechnology* will be particularly relevant to the future of this research project because of *size* dimensions. For example *nanomeasurement* is the manufacture of structures with dimensions that measure up to 100 nanometers. If such size dimensions will exist, we can envisage extraordinarily minuscule quantities of smells, medication - or any other substance, literally being built and 'pumped' around fabric surfaces.

13.2 Nanotechnology

"Nanotechnology is to the Nineties what cyberspace was to the Eighties" (ref 141)

"Nanotechnology. So incredibly small you cannot see it . . . . . " (ref.142 & fig.66)

Twenty two years ago a student at M.I.T began to wonder what it might mean if we could manufacture things the way life does, and how it might change the world. Eric Drexler, a chemist researching into molecular systems, has been described as a futurist, the 'Nanonerd guru' or 'Mr Nanotechnology' and was quoted at the beginning of the thesis on page xix.



The Meat Machine

In 1986, Drexler [1] wrote a book called 'Engines Of Creations', causing mixed reactions. Engineers and Scientists read it and understood that there was a technical argument, whilst others saw it as wild 'science fiction' with no logic due to the lack of mathematics (ref.143). US Scientific and Technological Research establishments have on the whole ignored his research. Drexler became infamous for his early ideas on the 'meat machine', whereby he reasoned that the molecular level of a cow was just a machine that rearranged the atoms in grass and a bit of water and then turned them into a beef steak. Subsequently, he believed that it would be possible to *BUILD* a machine which would do the same, only more efficiently to solve the world's problem of food, so it was not surprising that he was considered a little crazy! Like all other Nanoists, Drexler predicts that *Nanotechnology* is inevitable and will be enormous in 20 years. The subject still remains largely an object of curiosity to the scientific community and Drexler says : -

"Scientists are basically far too afraid to think far into the future"

Not all Nanoists agree with that but they do see that one day it will be possible to create miniature factories at the molecular level. Nanoist engineers seek to make complex structures from atoms similar to nature building trees, mountains and humans out of molecular raw mate

Wellness Research

In general *Nanotechnology* is still considered by many Scientists as fantasy - although the subject is widening and undoubtedly changing. During this project a fascination and curiosity into this particular subject developed and even though this project is designed-based - and *not* directed on

[1] Chairman of the Foresight Institute and research fellow at the Institute for Molecular Manufacturing, California

a purely scientific level. Having met the musician Brian Eno,[2] who is also interested in Drexler's vision - research was undertaken to discover exactly where *Nanotechnology* stands in the UK. Dr George Dodd already works for the *Nanotechnology* Centre at Glasgow University where they are continually improving the second generation 'electronic nose' (as discussed in Chapter 5). Although it was virtually impossible to squeeze information regarding *Nanotechnology* out of the Department of Trade & Industry and British Scientists and Engineers, conversations occurred during the 'lead-up' to the PhD's supporting film[3] (ref 144). This gave an idea of the sheer complexity and 'top secret' nature this new *extraordinary* science involves - and will perhaps, hold for the future. However, it was interesting to be able to freely discuss the meaning of *Nanotechnology* and receive encouraging feed-back from ideas involved with this project, involving technology miniaturisation, for *invisible clothing* as a future carrier.

Billion Dollar Future

Nanotechnology is attracting huge investment, with a market value estimated at £40bn in the next 10 years (ref. 145). NASA'S Ames Research Centre is becoming a significant funding force in *Computational Molecular Nanotechnology.*[1] But teams trying to make such systems such as gears the size of pollen grains and electric motors smaller than a pinhead find it is difficult to put the pieces together without dropping them. George Whitesides of the chemistry department at Harvard University (ref. 146) has produced millimetre sized plastic components and aims, in the next ten years - to make machines which could be used to manufacture microelectronics and mechanical systems.

13.3 Nano Robots

Self Duplication

Nanotechnology is the use of microscopic robots which can work with individual molecules of matter (ref. 147 & fig. 67). Scientists around the world are working on tiny insect-like super microgadgets out of bulk materials which build replicas of itself and so infinitum. The working parts would be as small as protein molecules and look like shrunken versions of 19th century mills. However, rapid "self-duplicating" machines for certain materials could cause endless danger and many more hurdles - both technical and economic - are necessary. *Nanotechnology* exists for moving individual atoms around so it may be possible to build microscopic machines with moving parts. According to Drexler - acoustic waves can be used to supply power to

[2] Eno, who collects his own library of 'smells', is also very interested in exhibiting 'smell' as an interactive art form
[3] A film called THE WELLNESS COLLECTION - *A Science Fashion Story* by Jenny Tillotson 1997
[1] The design and simulation of programmable molecular machines

assemblers for communication, navigation and massive internal computing purposes. In 1959 it was claimed that if a robot could make a smaller version of itself, and that robots could in turn make a smaller version of itself, the end result would be an invisible - but still working - robot, small enough to manipulate individual atoms and so would be able to "build" anything from cars to hamburgers to skyscrapers - molecule by molecule from the bottom - up. A race of these nanobots could be programmed to produce any structure allowed by the laws of matter. Originally the concept came from 'machines that could make machines of itself', thought up by mathematician John Von Neumann[2]

David Braunstein a Bioapplications scientist at Park Scientific Instruments, says : -

"What nanotechnologists are after is nothing more and nothing less than to understand and extend what nature already does. . . "

Bacteria-sized Robots

Nanobots mini-machine bacteria-sized are like insects a tenth of a micron[1] . They would all have active and passive protection mechanisms incorporated into them by law. ACTIVE protection

Nanotechnology is the use of microscopic robots which can work with individual molecules of matter

It is to the Nineties what Cyberspace was to the Eighties.

Scientists across the world are working on tiny, insect-like *nanobots*

would come from a self-destructive mechanism triggered by a chemical - rather like an antibiotic,

[2] Involved in Artificial Life
[1] A millionth of a meter

ensuring that no machine could self duplicate without the presence of some uncommon chemical making up the passive protection[2] . With future nanomachines - we will always know their construction and will have incorporated protective mechanisms

Applications

Drexlers further believes that *Nanotechnolgy* will contribute towards the end of diseases by implanting tiny nanobots or nanosubmarines in the body which would be 'programmed' to destroy cancerous cells or purify the lungs of a chronic smoker. Complex devices would therefore literally wander around the body fixing illnesses acting as subunits, linking together into objects that change shape to perform virtually any given task. Sometime in the next millennium, such machines could be injected into people to clean up their blood, rather like the visually stimulating movie "Fantastic Voyage[3] . Devices could perhaps alleviate hunger and guarantee biblical life spans by killing microbes. In dentistry, nanorobots would be the size of a microbe that will painlessly refurbish a tooth or build a new one. Nanomachines would revive bodies preserved in cryogenic storage by repairing frostbite damage to the brain and other organs[4]. It could also clean the environment and make space travel common by allowing the manufacturing of strong, light materials that go into smaller space transport vehicles. *Nanotechnology* consequently would produce more powerful computers, design new drugs and take super precise measurements. It makes silicon look like sand. Or even crazier - solve housing problems by 'growing' homes from diamonds - which is another form of carbon - like coal and will become one of the readily available substances on earth.

[2] For example, a robot may not injure a human as described in the 1941 Isaac Asimov law
[3] Richard Fleischer's 1966 Science Fiction 'Inner Space' film with Raquel Welch
[4] Drexler wants to personally do this to his own body after death

On The Dark Side

Nanotechnology claims *" to save or destroy the planet with submicroscopic machines".* Despite the many *'could's',* there are perhaps a few nightmares. Assemblers might streamline the production of superweapons. Nanodevices may well replicate uncontrollably, like malignant tumour cells, reducing everything to dust - but Drexler fights back, saying his nanomachines will have an underlying essential grounding in chemistry, physics and biology.

Nanotubes

Single-walled 'ropes' of nanotubes are being developed at Rice University in the USA, led by chemistry and physics professor Richard.E.Smalley. (ref. 148) His group has optimised a synthetic method of producing single-wall nanotubes using two different laser pulses to vaporise a graphite/metal composite rod inside a flow tube heated to 1200 degrees centrigade in an oven. Recent applications for the single carbon nanotube include the tip of an atomic force microscope, a centimetre long although it is predicted that soon it will be possible to produce continuous lengths that can be wound in a spool.

13.4 Conclusion

Atom By Atom By Atom

If all this is really going to be possible, and by proclaiming that **'Smell Is Nanotechnology**', microscopic machines and supercomputers could soon be built atom by atom with the help of a laser. For example, a new laser has recently been developed by Dr Wolfgang of M.I.T. (ref. 149) which works by cooling atoms to just above zero, at which point they slow down enough for their movement to be accurately controlled. (Bio)Chemical 'electronic noses' will be capable of discerning specific smells, substances and chemical reactions. Using the latest *Nanotechnology* olfactory equipment, this is currently being developed at the IBM Zurich Research Laboratory in partnership with the University of Basel, Switzerland (ref. 150). The principle is based on a micromechanical sensor which is super sensitive, showing mechanical responses from chemical and physical reactions such as stress, heat or mass change.

A Fantastic Voyage

If these nanomachines will eventually travel around arteries repairing diseases, then it will be possible to integrate *nano* machines into a single fibre, subsequently woven, knitted or implanted into fabric structures. The general idea could therefore pulsate perfume, deliver medication or anything else, using *Nanotechnology*, through hollow *nano* fibres and tubes.

Chapter 14

14 The Wellness Conclusion

14.1 Research Achievements And Novelty

The research initially set out to develop fabric proto type, intended for fragrance delivery alone. Consequently it has turned into a fully fledged project, using medical devices to solve delivery mechanism as a wearable agent, utilising the body as a site for exploration, as well as a new platform for technology. The project now focuses towards non-invasive therapeutic diagnostics, integrating *micromachines* and *biosensing* technology in future clothing.

Fabric is the starting point and the single most essential component whilst designing. Humans communicate thoughts and emotions to one another. The purpose of these clothes is therefore to enhance communication, well-being, and human interaction. The research identifies that computers will vanish as software is integrated into clothes. Future technology will evidently miniaturise, allowing an 'electronic tap' or chip to become part of the fibre. Fragrances will subsequently be released through holes (like garden irrigation systems) New fibres, based around 'multi-lumen' tubes, will transport different fluids or information, triggered by an impulse.

A new system is therefore created whereby the fragrance effect will be 'recharged', by refilling fibre channels in fabrics. The objective is to eliminate problems relating to odour time span, giving the consumer the possibility to *re-add* chosen fragrances and medication. It should also create an ecologically sound system whereby there is no wasted fragrance or medication and the individual is able to control the exact amount required. The research has also discussed *dynamic surface*s which is the more resilient 'outer-shell' dermis and protective fashion fabric. It is the harder, tougher, coat of armour; withstanding wear and tear, heavy blows - whilst holding and fighting dirt. However, it must maintain *comfort, softness* and protect the warmer 'inner-telligent dermis'. This is responsible for controlling and 'triggering' interactions in the fabric in order to calm or 'heal' the body. Fabric, the most familiar, tactile and friendly material in our lives, therefore stretches forward with the forefront of technology, creating entirely new ways of communication and self diagnosis, towards a healthier life.

14.2 Brief Summary Of Research Discoveries

Major discoveries include extensive research documented from the Medical Device Trades Shows in March 1996 and 1997. The project has identified state-of-the-art micro tubes used in medical, space and computer industries. Other fields include a vast range of electronic and transdermal drug delivery techniques, the fast developing field of biotextiles, superabsorbent structures, natural and artificial medical textiles, pumping devices, biomedical sensors, the 'electronic nose', non-medical sensors, environmental fragrance devices, smart fabrics and 'objects with intelligence', new fibres, and information relating to Nanotechnology and how this might benefit future research. International company contacts which have been fully established are documented in the Appendices on page 137 including dates, names of individuals, and presentations, given by the research project to individual Research & Development Centres.

14.3 Documentary Film

Whilst writing up this thesis, a documentary film called **The Wellness Collection - *A Science Fashion Story***, has been made to support this thesis. The research proved extremely beneficial whilst searching for necessary *found footage* relevant to the film. This includes various illustrations adapted for animation, demonstrating the 'pulsating' effect (figures 4, 5 & 6). The film particularly highlights smart fabrics as the new 'second skin' borrowing images from Oxford Scientific Films, such as a snakes embryo, hearts, veins and blood corpuscles. Further contacts were established, drawing close attention from the Wellcome Institute Film & Exhibitions Unit, The National Heart & Lung Institute, The Centre for Biological & Medical Systems, St Mary's Hospital and the Oxford University Zoology Dept. Further a field contacts have been established with Nanotechnologists at Parc Xerox, the Foresight Institute and NanoThinc, California. The latter have consequently requested for this research to be advertised on their NanoWorld website, as a Consulting Editor. Contacts are subsequently listed in Appendices on page 137.

14.4 Final Working Proto-types

The practical conclusion to the research involves a MicroFlow *Levet pump*, documented in Chapter 9. Due to the incompatibility of internal mechanics with alcohol, it has proved impossible to 'pump' fragrances and so at this stage coloured water, rose and lavender water fully demonstrate displaying *smells* through micromachines. Micro tubes, acting as the 'vaporiser' are glued together with a strong medical adhesive are attached to fabric samples and clothing, by embroidery techniques and simple hand sewing.

14.5 *'Electronic Nose'* Applications In Smart Clothing

Once the 'nose' technology reduces to the size of a fibre (which will take at least ten years) applications could monitor and detect perspiration levels, humidity, body odour, pheromones and ovulation in women. Clothes would therefore be *triggered* by body smells in order for a new action to occur, enhancing moods, emotions and increasing confidence by releasing 'up-lifting' odours. 'Nose' technology should greatly increase applications in *Space Age* fabrics, by utilising 'olfaction' as a new sensing tool. Clothes should also detect abnormal skin levels, in order to enhance eating disorders by releasing 'food' appetising odours in anorexics. Finally, clothes could detect alcoholic levels before driving, food before eating, poisonous environments, infectious and sexually transmitted diseases or mental disorders - all of which are possible with *nose* technology.

14.6 Recommendations and For Future Research

Ideally the next step forward demands advanced research within a scientific research establishment and the modification of small drug delivery systems for fragrance release, integrated into clothing. One option is to continue on a post doctoral level at Imperial College with Professor Andreas Manz, Chair of Zeeneca/SmithKline Beecham Centre for Analytical Sciences. He has shown a particular interest in the long term potential of the project. Having worked for Ciba Geigy and Hitachi in the past his expertise includes : - micro pumping systems, chromatography, capillary electrophoresis (Drug delivery page 84) thermal and implantable biosensors, capillary electrochromatography, Iontophoretic devices (Medical textiles page 117) and micro fabrication of polymer devices. His suggestions would be to either try and raise funding from the public sector, or find corporate sponsors from both the fashion or textile industries *and* nano-fluid delivery industries, or finally search for major venture capital over a two year period, with access to ten people, technology and a small factory laboratory. Science and technology are inevitably the leading factors for future developments, combining a crucial 'marriage' with fashion and textiles.

Other possible options include further presentations to already established contacts in the perfume and textile industries - or future collaboration with researchers in smart materials.[1] The Wellcome Institute have stressed an interest in the research project pursuing an interactive exhibition on *smell,* once the long running 'Science For Life' exhibition terminates, in 1998.

[1] Cranfield University, Brunel University, The Media Lab M.I.T. USA, Stanford University, USA

Further possibilities have arisen focusing on separate different areas for future experimentation, such as **odour chemistry**. This was originally anticipated to take place with Dr Dodd. The design and selection of key impact odorants is essentially very important, as well as the compatibility of odours on fabrics. This is a separate area of research in itself and requires expertise in chemistry.

14. 7 What Future Collaborations Does The Project Hold Abroad

Contacts have firmly been established at the Institute of Microtechnology, University of Neuchatel, Switzerland, with the company MicroFlow (discussed in Chapters 8 & 9). Similar to this research project, they too have established contacts with Fragrance Industries, as well as major international contacts in *inhaler technology*. It is anticipated that future research and development will commence on completion of the PhD, utilising micro membrane silicon pumps as illustrated in figure 36. Current applications include ink jet printers and insulin devices, containing two chambers within the tiny structure. The true wonder behind these nano pumps confirms that they ***easily*** resemble a button or accessory. With future adaptation this will merge neatly into clothing.

The research project has already been presented to two leading International Fragrance Industries, whose Research & Development Centres are abroad.[1] A further fragrance company is presently showing interest in the potential of this project. It is safe to say that major fashion and perfumery houses abroad (assumingly in France) will evidently show increasing fascination and curiosity.

14.8 Significance Of Results - Where Will This Lead

Perfume Industries

The investigated research will undoubtedly provide a new vehicle for designer fragrances. Applications are therefore *interactive* as opposed to microencapsulation, which is non-interactive.

Pharmaceutical Industries

The project has identified state-of-the-art devices, having successfully extracted information from pharmaceutical contacts, listed in Appendices on page 137. Pumps will decrease whilst biosensor technology expands. Future micro-devices and *cabling* systems will require careful

[1] Givaudan-Roure in Zurich. International Flavours & Fragrances in New Jersey, USA

protection. Clothing is the obvious container, a perfect platform for monitoring and drug delivery - especially benefiting the elderly, as longevity increases and more drugs are readily made available to cope with the over growing population.

The Fashion & Textile Industries

Non-invasive therapeutic diagnostics cross-over with perfumery and fashion to create functional, wearable 'all-in-one' smart clothes. This will be unobtrusive and therefore suitable for absolutely any environment whether you are a lorry driver, a pilot, or just a perfume lover. The *smartness* will not only add therapeutic and *controlled* medical properties but enable communication to take place automatically, adding further fantasy, function and imagination for leading fashion designers. Fabric applications will dramatically increase as technology decreases in size with respect to knitting, weaving, bonding, embroidery, implanting and computer-aided-design.

It would be hoped that the research developments will cross over into 'non-fabric' areas : -

***Interactive* Environmental Fragrance Industries**

Fully miniaturised technology could be *further* disguised into appropriate stores, consumer goods, shop display units, restaurants, computers, furniture, computers, transport and public conveniences

Entertainment Industries

Once miniaturised to the extent where a disposable device could be economical as well as controllable, it would be feasible to implant interactive odour systems, for example in the arm of a cinema chair or a specifically worn 'cinema garment' (sold with the movie). Minuscule amounts of odours would be released by interacting with sounds from the movie *and* emotions from the viewer - far greater and more evocatively stimulating than the present 'smelly telly' technology.

Educational Purposes

The research technology intends to heighten *interactivity of the senses* in educational books and other forms of communication. It will predominantly improve the sense of smell in the forthcoming century, due to the endless resources the technology can be applied to.

14.9 Concluding Statement

Life + Smart = Wellness

By combining your life with smart clothing, you will have *Wellness*.

Appendices

The research library consists of extensive company contacts made since September 1994.

Contacts established by telephone, through letters or in person - by way of presenting the project.

Fabrics & Fibres

Akzo Nobel Fibres, Netherlands — Correspondence by letter May 1996

H Verbeeton - Manager Corporate Communications

Courtaulds Textiles. — Regular contact since 1994 - 1997

Joanna Bowring - Design Director

Courtaulds Fibres (R&D) Coventry — Presentation of research April 1996

Hilda Coulsey - Head of Technology Development

Roland Cox - Associate Fellow 'Courtelle'

Tom Burrow - Research Manager 'Tencel' Applications

Courtaulds PLC London — Presentation of research January 1996

David Wilkinson - Director of Fibre Division

Courtaulds Jersey Underwear — Correspondence March 1996

Lynn Jaremczenko, Marketing/Sales Director

DuPont Nylon, London — Regular contact since January 1995

Denise Ford - Design Manager

Les Jacques - Development Manager

DuPont de Nemours International Geneva — Contacted April 1996

DuPont Lycra Leicester — Correspondence May 1996

Kit Blake - Marketing Manager LYCRA UK

DuPont Engineering Polymers R&D USA — Contacted May 1996

Garigue (French) London — Visited since November 1995

Laurent Garigue - Manager of fine couture fabrics

Hoechst's Fibres, Germany — Contacted April 1996

International Wool Secretariat, Yorkshire Correspondence January 1996
K P Russell - Project leader - Woollen Yarn Development

Rhone-Poulenc Films & Fibres France Correspondence April 1996

The Textile Institute, Manchester Member since Sept 1994
Elizabeth Chapman - Information Services Officer

Textured Jersey, Leicester UK Presentation of research January 1997
Paschal Little - Product Development & Sourcing Director
Rachel Creamer

Fragrance Companies

Bush Boake Allen, UK Correspondence since October 1994
Jim Dunstable - Marketing Manager

Dragoco, Germany & UK Correspondence since October 1994
G.L Clarke - Director Fragrance Division
Catherine Disdet - Vice President Fine Fragrances Europe

European Flavours & Fragrances, Hertfordshire Correspondence October 1994
C.E Kersey - Managing Director

Elida Gibbs Limited, Leeds Correspondence October 1994
Mary Kent - Consumer Relations Officer
Ian Pritchard - Company Public Relations Officer

Firmenich SA Fragrance House Correspondence since October 1994

Givaudan-Roure Research Ltd, Surrey UK Presentation of research March 1996
John Ayres - Managing Director

Givaudan-Roure European Creative Centre, Zurich Presented to R&D March 1996
Dr Ahmet Baydar - Director Applied Research Europe
Dr Konrad Lerch - Vice President

International Flavours & Fragrances (GB) LTD — Close contacts since Sept 1994
Joanna Norman - Director of Area Communications — Sponsors since September 1995
Stuart Maconochie - Director
Frank Winter - Market Research
Catherine Mitchell

International Flavours & Fragrances, Paris & Holland — Close contacts since Sept 1994
Dr John Ramsbotham - Technical Director (Fragrances) — Sponsors since September 1995
Jean Pierre Mary - Perfumer Paris
Catherine Bru - O.E.B Manager
Nicole Dalmasso - Fine Fragrances & Cosmetics

International Flavours & Fragrances R&D USA — Visited March 1995
Steve Warrenberg
Craig Warren - Vice President Fragrance Science Dept
Marina Munteanu - Vice President

Procter & Gamble, R&D Newcastle — Presentation of research March 1996
Allan McRitchie - Research & Development

Quest International, Ashford UK — Visited March 1996
Martin Holme - Marketing Director

Robertet (UK) Ltd, Surrey — Contact since November 1994
C.A.M. Burnham - Director Perfumery Division

The Aroma Foundation, , Wester Ross, Scotland — Contact since Oct 1994
Dr George Dodd - Director

Takasago, Japan & Paris — Contacts made since January 1995

Unilever PLC, Research & Engineering Division — Regular Contact since January 1996
Professor Ian Shanks - Divisional Science Adviser

Medical / Pharmaceutical Research

Ciba Pharmaceuticals West Sussex UK — Correspondence since 1995
Dr Richard Mannion - Director of Development

GlaxoWellcome Pharmaceutical Development Division, Herts Dr AP Green - Director of Pharmacy Philip Connolly - Science Communications Manager/Public Affairs	Correspondence since November 1995
Intravascular Research Ltd, UK Charles Boucher - Director	Visited since Sept 1995
MicroFlow SA Neuchatel, Switzerland Joseph Hess - Director	Sponsors since October 1996
Monell Chemical Senses Centre, Philadelphia	Contacts since April 1995
Nortech Medical Ltd, UK (heat pads) Dr David Norton - Director	Correspondence since March 1996
ROCHE Pharmaceuticals France	Contacts made since March 1996
Smell & Taste Research Foundation, Chicago Dr A Hirsch - Director	Correspondence since December 1996
Smith & Nephew PLC London UK J H Robinson - Director	Correspondence since May 1996

Therapeutic Drug Delivery

(Transdermal, Osmotic, In vitro & In vivo)

ALZA Corporation USA Lolly Winston - Media Relations Robert Kriebel - Vice President Jeremy Swallow - Veterinary Director (Osmotic pumps)	Correspondence since October 1995
3M Health Care Ltd UK Roger Ward	Correspondence since March 1996
ELAN Corporation, Ireland Aiden King - Research & Development Des Foley - Transdermal Development	Correspondence since October 1996
Boehringer-Ingelheim USA	Correspondence since October 1996

Janssen Pharmaceuticals USA	Correspondence since October 1996
Zeeneca/SmithKline Beecham (Imperial College UK) Professor Andreas Manz - Analytical Chemistry	Regular contact December 1996
Marion Merrell Dow, USA	Correspondence since October 1996
Baxter International USA	Correspondence since October 1996
Ensyma SA Switzerland Joseph Hess & Professor Nico. De Rooij	Correspondence since October 1996
Johnson SC & Sons Inc. patches	Correspondence since December 1995
BSI Corp. Antimicrobial Surfaces USA	Correspondence since November 1995

Respiratory & Inhaler Development

Allen & Hanburys Ltd UK Malcolm Joseland - Research & Development	Correspondence since November 1995
Fisons Pharmaceutical Respiratory Development Centre Dr M.Shepherd, Manager of Device Technology	Correspondence since Dec 1995

Medical Delivery & Syringe Pumps

ALZA Corporation USA	Correspondence since December 1995

Go Medical Industries Western Australia — Correspondence since January 1996
Dr G. O'Neil - Director
Ian Sergeant - Product Designer

Graseby Medical Limited Watford UK — Correspondence since December 1995

IVAC Hampshire UK — Correspondence since December 1995

Micro-encapsulation & Micro-fibres

3M UK PLC, Bracknell — Visited November 1994
Bernard F.Turner - European Business Manager

Arcade Europe, Paris — Correspondence since October 1994
Muriel Chagnon - Design Director

Celessence Marketing & Licensing UK — Visited November 1994
Martin Wismer - Research & Development
Stanley Miller - Marketing Director

Goulds Encapsulation, Manchester — Visited November 1994
Allan G. Paterson - Technical Director

Papier D'Armenie — Correspondence since January 1996
Michele Silney - Research & Development

Scent Seal Inc. California — Correspondence since October 1994
Elaine Trebek-Kares - Research & Development
Tamara Zimmerman - Marketing

Webcraft Technologies Inc. UK — Correspondence since October 1994

Japanese Microfibres & Encapsulation

Asahi Chemical Ind KK Japan — Correspondence since March 1995

Dai-Nippon Printing Co Japan — Correspondence since March 1995

Fuji Spinning Co Ltd, Osaka	Correspondence since March 1996
Kanebo Ltd, Japan Y.Yamashita - Deputy General Manager London	Correspondence since January 1995
Kobayashi Pharmaceutical Co Japan	Correspondence since March 1995
Kuraray Co Ltd Osaka	Correspondence since March 1995
Matsui Shikiso Chemical Co Ltd, Kyoto	Correspondence since March 1995
Mitsubishi Rayon Co Ltd Tokyo	Correspondence since March 1995
Pigeonwill Corp., Tokyo	Correspondence since May 1995
Toray Europe Ltd, London	Correspondence since May 1995
Toray Industries Inc., Tokyo	Correspondence since May 1995
The Okomoto Research Lab (Toray) Japan Dr M. Okomoto - Research & Development	Regular contact since January 1995
Unitika Ltd, Osaka	Correspondence since March 1996

Medical Tubing's

(Micro silicon, rubber, urethane, pulsed, wall reinforced tubing's, multi-circuited tubing's)

Adam Spence USA Patrick Mulholland - Manufacturing Manager	Correspondence since March 1996
Advanced Polymers Incorporated USA John Porto. Jr - Sales Manager	Correspondence since March 1995
Altec Products Limited Hampshire UK June Hayden - Office Manager	Correspondence since November 1995

Bibby Sterilin Ltd Glamorgan UK	Correspondence since October 1995
AK. Rowlands - Customer Services Esco Rubber	
Dow Corning European Health Care France	Correspondence since March 1996
Nathalie Thomas	
DSM Engineering Plastic Products UK	Correspondence since March 1996
Ellay Inc. USA	Correspondence since March 1996
Allen Edmond	
Infus Medical Co Ltd, Thailand	Correspondence since March 1996
Chookiat Chanarat - Managing Director	
Intercobra Limited Scotland	Correspondence since March 1996
Gayle Bally	
Kimal Manufacturing Ltd UK	Correspondence since March 1996
Mr P.A Talbot - Director	
Microfil Industries SA Switzerland	Correspondence since March 1996
Eric Broulis - Director	
Minitubes France	Correspondence since March 1996
Phillipe Poncin	
MS Techniques France	Sponsors since March 1997
Monsieur E. Malher - Director	
Nolato Polymer AB Sweden	Correspondence since March 1996
Norton Performance Plastics	Correspondence since March 1996
Susan Hulson	
Optima, Scandinavia, Sweden	Correspondence since March 1996
Peder Peterson - Sales & Marketing Director	
Popper & Sons, New York USA	Correspondence since March 1996

Joseph popper - Director

Putnam Plastic Corp., USA Correspondence since March 1996
Jim Dandeneau - President

SF Medical Tubing's, USA Correspondence since March 1996
Mr Jim Walton - Director

The West Group Fluid Power Centre Ltd, UK Correspondence since March 1996
Geoff Collins - Field Support Manager

Zeus, Orangeburg USA Correspondence since March 1995
Jeffrey Lamb - International Division Supervisor

TFX, Limerick Ireland Correspondence since March 1996
Ciaran Hood - Engineering Manager
Padraig Barry - General Manager

Medical Devices

(Laboratories Suppliers, Catheters & Safety Systems)

Aeromedic Innovations London UK Correspondence since November 1995
Lawrence Harding - Director of Pharmacy

AJ Cope London UK Correspondence since November 1995

Applied Chromatography UK Correspondence since November 1995

Boots The Chemist Nottingham UK Correspondence since November 1995

Converters Inc. USA Correspondence since November 1995

Go Medical Industries, Western Australia
Dr George O'Neil - Director of Infusion Pumps Correspondence since January 1996
Ian Sergeant - Product Designer

ICI Acrylics Lancashire UK Correspondence since December 1995

Michael Cass - Perspex Technical Director
Dr Lombard - Research & Development

Jencons (Scientific) Ltd Leighton Buzzard UK Correspondence since November 1995
Helen Payne - Area co-ordinator

Johnson & Johnson Medical Ltd Berks UK Correspondence since November 1995
Shelly Bucknall

LIG Supplies Ltd UK Correspondence since November 1995

Menlo Care California USA Correspondence since November 1995

Merck Poole UK Correspondence since November 1995

Omnifit Medical Devices, Cambridge Correspondence since November 1995

Orme Scientific Limited Manchester UK Correspondence since November 1995
Denise Brown

Qosina Corp. USA Correspondence since March 1996
Claudia Cala - International Sales

SIMS Smith Industries Medical System UK (Portex) Correspondence since October 1995
John Redmond - Public Sector Director

Vygon (UK) Ltd Correspondence since January 1996
A.S Costello - Business Development Manager

Medical Adhesives For Tubing's

Adhesives Research USA

Eastman Chemicals BV, The Netherlands

Innovative Technologies Group PLC, USA

Intertronics UK

Maspac Limited Ireland

NMI, Germany

NuSil Technology, USA

Loctite UK Limited Correspondence since March 1995

John Tennant - Business Manager

Statice Sante Industrie Biomedicale Correspondence since March 1996

Serge Piranda - President Director General

Tolas Health Care Packaging USA Correspondence since March 1996

Leslie Love - Components/Conductives Co-ordinator

Textile Institutes

Deutsches Textilforschungszentrum Nord -West Germany Correspondence since January 1997

Ulrike Denter - Textiles Researcher

Smart Materials

B&H Liquid Crystal Devices Ltd, London Visited November 1995

Global Inc. (liquid crystal) London Visited January 1995

Jonathan Sieff - Director

Gorix Electro-Conductive Fibres, UK Correspondence since March 1996

J.R.Rix - Product development Manager

Nuno Corporation Tokyo, Japan Contacts since May 1995

Mizue Okada

The Okomoto Research Lab (Toray) Japan — Regular contact since January 1995
Dr M. Okomoto - Research & Development

Teijin Shoji Co Ltd Japan — Correspondence since January 1996
Mr M. Jinde - Director

Warcoal Lingerie Japan & Paris (Memory Metals) — Correspondence since October 1995
Sophie Desegher (Paris)
N. Fiujioka (Japan)

Performance Fabrics

Carrington Performance Fabrics UK — Correspondence since July 1996

International Performance fabrics (IPT (UK) Ltd — Correspondence since July 1996

Rubatex, Cellular Rubber (UK) Ltd — Correspondence since January 1996
J.R. Murray - Sales Manager

W.L.Gore & Associates , UK — Correspondence since March 1995

Welbeck Technical Textiles, UK — Correspondence since January 1996
John Morris
Jonathan Wynn - Consultant Geotechnical Engineer
Glenn White (Du Pont)

Medical Mesh Fabrics

AFC World-wide USA — Correspondence since March 1996
Roy. M. Kaufelt - International Sales Manager

Fyltis Filtration Industrielle, France — Correspondence since March 1996
W.Patton

Precision Textiles Limited — Correspondence since March 1996
Chris Sheridan - Area Sales Manager

ZBF Mesh & Technology Switzerland Correspondence since November 1995

Gardening Equipment

Gardena (UK) Ltd

Precise Irrigation UK Ltd

Zifir Agriculture

Peristaltic Pumps

Watson/Marlow Pumps UK Experimental Sponsors since Dec 1996

Martin Johnson - Technical Engineer

Bruce Quilter - Technical Engineer

Altec Products Limited Hampshire UK Correspondence since November 1995

June Hayden - Office Manager

FMI Pumps, Oyster Bay USA Correspondence since October 1995

Electronic Nose Technology

AromaScan UMIST UK Correspondence since April 1995

Buchannan Communications

GEC Marconi Materials Technology Correspondence since November 1996

Mark Byfield (and Scientists at Firmenich SA)

IBM Research Divisions Unit, Zurich Correspondence since March 1995

Neotronics Scientific UK Correspondence since March 1995

Nanotechnology Centre Glasgow University Contacts made since October 1994

Dr George Dodd & Prof John Barker

Dr Hywell Morgan & Dr John Cooper

Nanotechnology

Nanotechnology National Physics Laboratory, UK Correspondence since February 1997
Peter Kendal

DTI Science & Technology UK Correspondence since February 1997
Chris Hamlin

Warwick University Nanotechnology Correspondence since February 1997
Harry Hingle

National Microstructure Faculty Correspondence since February 1997
Professor Ron Laws - Research & Development

Foresight Insight USA Correspondence since February 1997
Judy Hill - Office Manager

Parc Xerox, Palo Alto, USA Correspondence since February 1997
Ralph Merkle - R&D Molecular Engineering

University Of Birmingham Chemistry Dept Correspondence since February 1997
Fraser Stoddard

Micro Electronics

Q Cards London (sound microchips) Contacts made October 1994
R.J.Melwani - Director

Techno Mind Ltd, UK (electronic sound microchips) Correspondence since January 1995
Geoffrey Lee - UK & European Manager

Sounds Tactics UK (commercial microchips) Correspondence since February 1995
Don Hockman - Director

Spencer Childs Regular contact since December 1995
Electronics & Software Consultant

Sequoia Technology Limited, UK Correspondence since February 1996
Craig Lowe - Product Group Manager

Fabrex, Leics, UK Correspondence since February 1995

Michael Grove - Sales Executive

Mr Victor de Menzies - Imperial College Correspondence since February 1995

Physics Dept - Electronics

Environmental Fragrancing

BOC Gases UK Visited November 1995

Nicholas Bewes - Manager New Product Development

Hercules Inc. Air Fresheners Correspondence since January 1996

Breath Sensors

Lion Alcohol Sensor Laboratories PLC Contacted January 1996

The Metropolitan Police Force

Ink Jet Printers

Hewlett & Packard UK Correspondence since January 1996

Mr R Handscott

Epsom (UK) Limited Correspondence since November 1995

Joanne Whitbread - Marketing Department

Medical Textiles

BASF AG Germany

Innovative Technologies Ltd UK

Conva Tec Medical textiles WHRI UK

Seton Healthcare Group PLC UK

BSI Corp. Antimicrobial Surfaces USA

Smith & Nephew PLC London UK

Military/Space

NASA Ames Research Centre Correspondence since February 1997

Al Globus & Levit - Computational Nanotechnology

Defence Clothing & Textiles Agency UK Correspondence since June 1996

Dr Richard Scott - Research & Development

Surgery

St Marys Hospital London Contacted September 1995

Dr Dorsey - Minimally Invasive Surgery

Imperial College, London Contacted September 1995

Dr Brian Davies - Micro Surgery

Synaesthesia

Charing Cross & Westminster Medical School Correspondence since November 1994

John Harrison - Neuropsychologist

Institute of Psychiatry - Dept of Psychology Correspondence since November 1994

Simon Baron - Cohen - Psychologist

Misc

Victoria Secrets Lingerie, USA Regular Contact since March 1996

Neil Goren - Managing Director

John Bell & Croydon, Pharmacy London Regular Contact since March 1995

Mike Skimin

Dale Air Products, Blackpool Contacted October 1994

Fred Dale - Smell Specialist for Museums

The Body Shop International PLC Correspondence since January 1995

Paul Ralston - Marketing General Manager

Dr Aran Puri

Lee Products Limited - Innovation In Miniature Correspondence since March 1995

Roger Brooks - Sales Engineer

Shiseido Kate Broadhurst PA to Managing Director	Correspondence since February 1996
Brian Eno	Correspondence since October 1996
Rebecca Horn, Berlin Kinetic Artist	Contacted January 1995
Susan Kasen Summer, New York USA Dimensional Media Associates, Vice President SONY	Contacted January 1995
Virgin Atlantic Airways Richard Branson - Chairman	Contacted March 1996

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Givaudan-Roure European Creative Centre UK & Switzerland

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Procter & Gamble, Newcastle UK

Quest International, Ashford UK

Unilever PLC UK

Takasargo Japan & Paris

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Arcade Europe ScentStrips, DiscCover 1980, Paris

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Ref 101 Hilda Coulsey - Head of Technology Development for Fibres & Chemicals

Roland Cox - Associate Fellow 'Courtelle'

Tom Burrow - Research Manager 'Tencel' Applications

David Wilkinson - Director of Courtaulds Fibres PLC

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Dr Hywell Morgan, Bioelectronic Research Centre, University of Glasgow 1997

Dr John Cooper - Bioelectronic Research Centre, University of Glasgow 1997

Dr Michael Pycraft, Bioelectronic Research Centre, University of Glasgow 1997

Professor Fraser Stoddard, School of Chemistry, Birmingham University 1997

David Bloor, Dept of Physics, Durham University 1997

Chris Hamlin Department of Trade & Industry, Science & Technology 1997

Al Globus - NASA - Ames Research Centre, USA 1997

Ralph Merkle, Lois Wong, Parc Xerox, California USA 1997

Paul Green - Chairman - Nanothinc. A Californian Corporation USA 1997

Professor Ron Laws - National Microstructure Facility, Rutherford 1997

Peter Kenal - Nanotechnology National Physics Lab, Teddington

Marc Weiser - Parc Xerox, California USA

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Kennett. F : CoCo - *The Life & Loves Of Gabrielle Chanel*

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Trade Fairs

Techtextil - Technical Textiles Frankfurt - June 1995

Medical Device Technology Trade Show - Olympia March 1996

Medical Device Technology Trade Show - Olympia March 1997

Medical Textiles - Bolton Institute, July 1996

Premiere Vision Fashion Fabrics - Paris, September 1995

Premiere Vision Fashion Fabrics - Paris, September 1996

Sensors & Temperature Control - Birmingham NEC, March 1996

The Great British Innovations & Inventions Fair - Barbican Centre London March 1996

Mind, Body Spirit 19th International Festival - The Royal Horticultural Halls London 1995

Mind, Body Spirit 20th International Festival - The Royal Horticultural Halls London 1996

Conferences & Exhibitions

Techtextil Conference - Frankfurt, June 1995

Medical Textiles Conference - Bolton Institute Of Textiles, July 1996

The Medical Design & Materials Conference - Olympia, March 1997

Heavenly Scent - The Royal College Of Art, March-April 1995

Television Shows

Horizons BBC Nanotopia *(Nanotechnology)* 13 Novemeber 1995

Horizons BBC Orange Sherbet Kisses (*Synaesthesia)* 12 December 1994

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Super Sense BBC Super Scents January 1989

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Journals

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Horizons	Contacts since November 1995
Insight - Nanotechnology	Regular Contact February 1997
Marie Claire UK	Work Published October 1995
Medical Textiles	Work Published July 1996
Nanothinc WWW Internet	Regular Contact February 1997
Textile Forum	Work published January 1996
Technical Textiles Journal, UK	Regular Contact since Sept 1994
The Sunday Times Magazine UK	Work Published March 1996

Glossary

Absorption	The act of taking up and transforming (energy) instead of transmitting or reflecting, sucking up or swallowing up.
Accord	The harmonious association of several raw materials, and the resulting olfactory effect
Adsorption	To take up a vapour on its surface
Alcohol	Denatured ethyl alcohol, 96% proof. Used as a neutral solvent in preparing fragrances and added to the concentration as a vehicle for the oil, modifying its intensity and making it easily applicable to skin.
Aldehyde	An organic chemical containing the group carbon, hydrogen and oxygen atom that can be derived from natural or synthetic materials (*Chanel No 5* was the first aldehyde-type fragrance)
AromaCology	A perfumery term for the *headspace technology* of capturing smells
Aromatherapy	A therapeutic treatment which enhances well-being (or 'wellness') relieves stress, promotes good health and vitality, and greatly complements other forms of therapeutic treatments.
Anosmia	The loss of the sense of smell
Apocrine glands	Specialised glands, secrete a milky substance with properties allowing bacterial action to convert it to *pheromones*. Human apocrine glands are found (with hair glands) around the nipples, genitals, armpits, scalp, under the nose, on the forehead at the base of the eyelashes and in the naval area.
Artificial Intelligence	A field of research that aims to understand and build intelligent machines, referring also to an intelligent machine itself

Axilla	The underarm area or armpit.
Biomimetric	The science of copying natures most useful features
Biosensors	Analytical devices responding and converting concentrations into an electrical signal via a biological recognition system and an electrochemical, optical or other transducer.
Biotechnology	The use of micro-organisms to create synthetic odorous molecules. Progress is now being made in genetics, plant cells producing essential oils have been successfully cultivated in vitro.
Biotextile	A complex biologically active and *fibrous* drug delivery material
Capillaries	Microscopic blood vessels that carry oxygenated blood to tissues
Capillary Electrophoresis	A technique with liquids in microbore systems and rapidly developing analytical area popular in 'drug delivery', relying on electrical charge to drive molecules through fine capillaries effecting separation of similar molecules due to small differences in charge and size.
'Cashmaran'	A magical molecule invented by the chemist Bill Taylor (*International Flavours & Fragrances)* used in fabric conditioners
Cell	A membrane-bonded unit, typically microns in diameter. All plants and animals are made up of one or more of cells (trillions in human beings) In general, each cell of a multicellular organism contains a nucleus holding all of the genetic information of the organism.
Chitin	The substance which forms most of the hard parts of insects, millipedes, shrimps, lobsters and mushrooms

Chromatography Method of scientific analysis enabling one to identify and calculate the extent of a molecule's presence in essential oils, enabling researchers to discover new odorous molecules.

Civet The thick yellowish, musky-smelling fluid secreted by Ethiopian civet cats, or a synthetic product used in perfumes. In its natural state it is nauseous. Only when diluted does it acquire a sensual aroma.

Collagen A protein in fibrous connective tissue, readily turned into gelatine

Composite Constructed materials from a mixture and variety of elements

Cycloidal Vibration Moving in a 3 way direction - north/south, east/west, and in a circular direction, all at the same time

Dielectric Transmitting electric effects without conducting

Distillation Ancient method of extraction using a steam, used in Mesopotamia as a early as 5000 BC and rediscovered by Avicenne in AD 10000, undergoing constant improvements

Dynamic Relating to *activity* and the energetic effects of forces in nature

Eccrine Glands Glands that secrete a watery sweat onto the skin and are found over most of the body, their secretions keep the body cool.

Electronic Nose A perfect replica of a *human nose*, sensing and detecting odours and mimicking the three phases of the human olfactory system using a computer as the 'brain'

Electroplating A method of plating one metal with another electromechanically

Electrotransport Low-level electrical energy developed to assist the transport of drugs such as proteins and peptides, across the skin.

Endorphins	Naturally produced peptide hormones that bind to opiate receptors (acts similarly to opiates) which reduce pain and affect emotions.
Engineering	The use of scientific knowledge and trial-and-error to design systems
Enzyme	A protein that acts as a catalyst in a biomedical reaction
Essential Oil	Fragrant volatile extracts obtained from aromatic plant elements using distillation, expression, extraction, enfleurage or *headspace technology.* Oils are the basic ingredients employed by perfumers and mixed with 96% proof alcohol in strictly prescribed proportions.
Exocrine Glands	A salivary/sweat gland that secretes its protein through a duct
Fixative	A substance added to a perfume to slow the rate of evaporation.
Fluoropolymers	A high-technology plastic engineered by DuPont in resin or pellet form
Fragrance	Derived from the Latin fragrance (*to smell*) it denotes a pleasant odour or skilful association of harmonious odours
Genetic Engineering	A range of techniques for manipulating DNA and thereby modify the genetic structure of living organisms
Gland	A cell, group of cells or an organ that produces a secretion for use elsewhere in the body, or for elimination from the body.
Headspace Technology	A method for analysing odours present in the air involving chromatography, developed 20 years ago. After analysis, identity cards, corresponding to this odour are drawn up, which after interpretation by the perfumer enables him to reconstitute the odours. Headspace enlarged the perfumer's palette, providing fresher raw materials, very close to nature - and more creativity.

Hippocampus	A part of the brain's limbic system containing nerve cells that play a central role in memory processes.
Hyposmia	The reduced ability to smell certain odours which may be either a temporary or permanent condition.
Impregnation	To saturate or fill with particles or qualities of another thing.
In vitro	In the glass, test tube or out of the living organism
In vivo	In the living organism
Integrated Systems	An electronic circuit consisting of many inter-connected devices on one piece of semi-conductor, typically on 1-10 millimetres on a side
Interactivity	Mutual action allowing two-way communication
Invasive Therapy	Administrating closely monitored substances with an injected needle
KIO'S	"Key Impact Odorants" in humans
Limbic System	A group of interconnected structures deep inside the brain which are common to all mammals. They are involved in olfaction, emotion, motivation, behaviour, and in various autonomic functions.
Mammal	A warm-blooded animal with an internal skeleton and with other characteristics like a covering of hair on the skin.
Micro-encapsulation	The process in which tiny talc particles or droplets (invisible to the naked eye) surrounded by a coating make small capsules with useful properties. Once the coating is broken, droplets are released on fabrics, wool fibres or other woven or non-woven surfaces

Molecule The smallest part of a chemical substance, typically a group of atoms held together in a particular pattern by chemical bonds.

Multi-lumen Multiple spaces within a cell wall. For example in a tube system

Multi-sensorial Interaction between all five senses - *smell, touch, taste, sound, vision*

Musk (Muscone) A greasy secretion with a powerful odour, produced by animals, or a synthetic product used in perfume.

Nano A prefix meaning ten to the minus ninth power, or one billionth

Nanotechnology Technology based on the manipulation of individual atoms and molecules to build structures to complex, atomic specifications

Nature The internal processes and functions that determine an organism's essential characteristics as they are found in its primitive state of existence, untouched and uninfluenced artificially or by socialisation. Genes determine an organism's nature.

Nerve A cordlike bundle of axons that allows sensory stimuli and motor impulses to pass between the brain or other parts of the central nervous system and other parts of the body.

Neurone A nerve cell, such as those found in the brain

'Nose' Colloquial term for a perfumer. Although his nose is the principle tool, the art is to use judgement, refined taste and memory

Note Term borrowed from music designating an olfactory impression indicating three parts of fragrance. ie: - *top, middle and base notes.*

Nylon The generic term for all synthetic polyamides

Odour	The property or quality that affects, stimulates,or is perceived by the sense of smell. A sensation, stimulation, or perception of smell
Olfaction	The sense of smell. The act of the process of smelling
Olfactory Bulb	The bulblike ends of the olfactory lobes where the olfactory nerves begin. They are found just above the nose in the floor of the brain.
Osmo	Greek for the science or chemistry of *smell* (**Osmical =** the adjective)
Osmotherapy	Trade word from the Olfactory Research Group - Warwick University
'pencil'	Hairs on an insect which are used to spread pheromones for mating
Perfume	Commonly used to designate the extract, the most concentrated form of fragrance - derived from the Latin *per fumum* (through smoke) It is a creative work of art and an aesthetic intention, the harmonious combination of many components.
Peristaltic	The forcing onward by waves of contractions
Pheromone	Chemical messages produced by a member of a species, influencing the physiology and behaviour of another member of the same species. Whether or not this message is consciously detected *(smelled)* pheromones have the same effect. In Mammals pheromones ("social odours") - that one member of a species is exposed to during interaction with another member - cause changes in hormone levels and in behaviour.
Human pheromones	'Aromatic' molecules which smell musky when we are sexually aroused and are found on our skin.
PEEK	Polyethereketone is insoluble in virtually all solvents, organics and inorganics, has excellent thermal and electrical properties, is resistant to radiation, ageing and high temperature hydrolysis.

Polyethylene A generic name for certain thermoplastics, polymers of ethylene

Polyiff Engineered fragrances for plastics (International Flavours & Fragrances Inc.) sold in pellet form

Polymer A molecule made up of smaller units bonded to form a chain

PPFF A keratin protein hollow fibre (6 nanometres diameter) made from the white feathers of chickens

PTFE *PolyTetraFluoroEthylene* has unique properties, unlikely to be beaten by any other plastic material, with low coefficient of friction and outstanding chemical resistance for the medical industry.

Receptor A special nerve cell that turns a sense *(sight, taste, sound smell or touch)* into an electrical signal which is sent to the brain. Receptor cells give the brain all its information about the outside world and feed information back helping the brain to work organs, ie: the limbs.

Sensors A device that detects a change in a physical stimulus and turns it into a signal which can be measured or which operates a control

Sex Pheromones Pheromones derived from the sex hormone of one member of a species that alter levels of sex hormones and behaviour in another member of the same species.

Scent The smell that is secreted when microscopic particles leave the scented object and become scattered in the air. When scent particles reach the nose they are dissolved in the mucus and turned into a chemical signal

Scent Strips Bands of paper sprinkled with microscopic perfumed capsules, which liberate fragrance, immediately the protective membrane is removed.

Sexual Synchrony	A pheromone-induced effect on the hormone levels of couples through which peak levels of testosterone coincide with peak fertility in the female. One report suggests that a similar phenomena occurs in homosexual male couples.
Shingosen	Japanese translation for *synthetic fibres*
***Smart* Interface**	A 'situation' where interaction occurs between two systems or the common boundary - and in this case, fabrics or clothing.
Spidroin	*A* revolutionary new fibre made up of two proteins from *spiders silk*
Splicing	To unite by interweaving the strands or join together by over lapping
Synaesthesia	The sensory 'mix-up' whereby sensations produced at a point different from the point of stimulation: a sensation of another kind suggested by one experienced (e.g. in colour hearing, shape tasting)
Tencel	Made from wood chips. The pulp is made into woven fibre by Courtaulds and looks like cotton but feels like silk
Thermochromic	Dyes which change colour when heat is applied
Transdermal	A technique allowing the *delivery* of a substance through intact skin
Triggers	Anything that starts a train of *action*
Volatile	The property of an odour possessing little persistence and which evaporates rapidly.
Ultrasound	Sound waves which are too high to be heard by the human ear
'Wellness'	*Wellness* is a derivative from *Well-being* aspiring to being 'well' and not 'ill'. Wellness as opposed to fitness is an approach to combating stress and boosting self esteem (in this case through active clothing)